THE STATE AGRICULTURAL COLLEGE
OF COLORADO

TWENTY-SECOND ANNUAL REPORT

OF

The Agricultural Experiment Station

For 1909

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** Term Began, April 14, 1909.
° Term Expired, January, 1909.
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°°° Term Began, January, 1909.
°°°° Term Began, June 2, 1909.
‡ Term Expired, April 14, 1909.
‡‡ Term Began, April 14, 1909.
† Term Expired, April 14, 1909.
†† Term Began, April 14, 1909.
§ To April 14, 1909.
§§ Since April 14, 1909.

369 88

STATION STAFF

L. G. CARPENTER, M. S., Director.....Irrigation Engineer
C. P. GILLETTE, M. S.....Entomologist
W. P. HEADDEN, A. M., Ph. D.....Chemist
WENDELL PADDOCK,* M. S.....Horticulturist
G. H. GLOVER, M. S., D. V. M.....Veterinarian
ALVIN KEYSER, A. M.....Agronomist
W. G. SACKETT, B. S.....Bacteriologist
J. O. WILLIAMS, B. S. A.....U. S. Expert in Charge Horse Breeding
E. R. BENNETT,*** B. S.....Horticulturist
P. K. BLINN, B. S.....Field Agent, Arkansas Valley, Rocky Ford
R. E. TRIMBLE, B. S.....Assistant Irrigation Engineer
F. C. ALFORD, M. S.....Assistant Chemist
EARL DOUGLASS, M. S.....Assistant Chemist
S. ARTHUR JOHNSON, M. S.....Assistant Entomologist
B. O. LONGYEAR, M. S.....Assistant Horticulturist
F. KNORR,† B. S.....Assistant Agronomist
MIRIAM A. PALMER.....Artist
L. C. BRAGG.....Assistant in Entomology
C. L. FITCH††.....Potato Investigations

STATE FRUIT INVESTIGATIONS.

O. B. WHIPPLE, †††.....Grand Junction, Field Horticulturist
GEO. P. WELDON, B. S.....Delta,§ Field Entomologist
R. S. HERRICK,§§ B. S.....Delta, Field Horticulturist

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* Resigned July 1, 1909, to become Professor of Horticulture, State University, Columbus, Ohio.

** Appointed, June 1, 1909.

*** Appointed, August 1, 1909.

† Resigned, March 15, 1909.

†† Appointed, October 15, 1909.

††† Resigned, July 1, 1909, to become Professor of Horticulture, State Agricultural College, Bozeman, Montana.

§ Transferred to Grand Junction, July 1, 1909.

§§ Appointed, July 1, 1909.

LETTER OF TRANSMITTAL.

To His Excellency, John F. Shafroth, Governor of Colorado:

In accordance with the conditions of the Act of Congress which requires a full and detailed report of the operations of the Experiment Station, I have the honor to present herewith the twenty-second annual report.

The financial statement is for the fiscal year ending June 30, the other portions being reported substantially for the current year.

The publication of the investigations is made in separate form as bulletins, and these are freely distributed among the people of the State.

L. G. CARPENTER,
Director.

The Agricultural Experiment Station,
State Agricultural College,
Fort Collins, Colorado,
December, 1909.

FINANCIAL REPORT OF THE COLORADO AGRICULTURAL EXPERIMENT STATION FOR THE FISCAL YEAR ENDING JUNE 30, 1909.

RECEIPTS.

DR.	HATCH FUND	ADAMS FUND	STATE FUND	SPECIAL FUND	TOTALS
From the Treasurer of the United States as per appropriation for the fiscal year ended June 30, 1909, under acts of Congress. Approved March 2, 1887, (Hatch Fund) and March 16, 1906, (Adams Fund)	$15,000.00	$11,000.00			
Balance on hand July 1, 1908	.....	.....	$13,027.39	$ 7,307.66	$20,335.05
Part of 1910 State App'r...	.....	.....	2,500.00	.....	.....
* Transfer	.....	.....	.....	6,710.62	.....
Other sources than the U. S.	.....	.....	.....	5,331.22	14,541.84
TOTAL RECEIPTS.....					$60,876.89

DISBURSEMENTS.

	HATCH FUND	ADAMS FUND	STATE FUND	SPECIAL FUND	TOTALS
By Salaries	$ 8,352.74	$ 8,005.54	$ 1,150.00	$ 3,134.24	$20,642.52
Labor	788.68	5.25	822.94	1,132.72	2,749.59
Publications	2,764.59	.....	.....	1,968.45	4,733.04
Postage and stationery...	693.85	52.37	74.79	128.66	949.67
Freight and express.....	277.48	42.25	2.30	377.94	699.97
Heat, light, water & power.	.....	.....	3.90	7.80	11.70
Chemical supplies.....	9.80	1,043.85	.....	7.60	1,061.25
Seeds, plants and sundry supplies	137.54	48.06	314.50	494.40	994.50
Fertilizers	.....	.....	.....	.....	.....
Feeding stuffs	.....	.....	.....	2,385.52	2,385.52
Library	199.06	42.82	.....	.....	241.88
Tools, imp'm'ts, & m'ch'y..	3.05	.....	27.25	51.00	81.30
Furniture and fixtures....	378.71	414.50	2.50	15.00	810.71
Scientific apparatus.....	10.00	321.49	28.94	292.82	653.25
Live stock	.....	.....	.....	1,067.03	1,067.03
Traveling expenses	669.50	722.67	294.80	532.00	2,218.97
Contingent expenses	15.00	.....	85.00	719.68	819.68
Buildings and land.....	700.00	301.20	3,534.85	1,560.08	6,096.13
** Transfer	.....	.....	6,710.62	.....	6,710.62
TOTAL EXPENDITURE...	$15,000.00	$11,000.00	$13,052.39	$13,874.94	$52,927.33
BALANCE			2,475.00	5,474.56	7,949.56
TOTAL			$15,527.39	$19,349.50	$60,876.89

* Special appropriation by State Legislature for the two years from December 1, 1908 to November 30, 1910, inclusive

** This transfer was made to reimburse funds from which money was borrowed to enable us to continue certain work before the appropriation was available.

REPORT OF THE DIRECTOR

Gentlemen: I have the honor to submit my report as Director of the Experiment Station for the year ending December first.

This period includes part of two Government fiscal years. The reports of the various members of the Station staff are attached. There are other questions more fundamental to be taken up so that if I discuss the matters of detail so much time will be required that I am afraid the more important questions might be passed over.

The financial situation of the Experiment Station is a troublesome one, but of a different nature from that of the College. Instead of a deficit there is a surplus accumulating. The funds are trust funds given under strict limitations both by Congress and by the State. They are not appropriations for College purposes, they are given as a means of doing certain work. The orderly progress of the work of the Experiment Station under the Director, as developed under the regulations recommended by the U. S. Department of Agriculture, and as developed under the practices of the past few years, has been practically suspended, and up to the present time no definite plan has been substituted. Recommendations and plans of work submitted by the Director have neither been approved nor disapproved. The Director's hands have thus practically been tied. The funds must be expended within narrow limits. Any portion of the Hatch or Adams funds unexpended on July 1st of next year are confiscated. Any expenditure not made in accordance with the law and with the regulations, must be replaced from other funds. It is going to be very difficult, if not impossible, now to use the funds in accordance with the law in the remaining portion of the Government fiscal year. It may be forgotten that the saving of expenditure of money is not a saving of our funds. It practically is the case that it is the unused balance in the Station funds that prevents a deficit in the College balances at the Bank, and a very large one. However commendable this object may be to prevent an apparent deficit and avoid paying interest at the Bank, the fact ought not to be lost sight of that so far as the Government funds are used for the purpose of avoiding the payment of interest, that this might lead to serious inquiry on the part of the Government, and it is not impossible that it might be considered as a perversion of the use. It might also lead to a claim for the repayment of the interest whose payment has thus been avoided.

It is very common to think of these funds of the Experiment Station as appropriations to the College, that is, as accessory to

College purposes, and the corresponding temptation to call upon these funds to help pay men for teaching, or to get apparatus whose function is teaching and not investigation. This is common, is not surprising and is especially probable at a time when College funds are comparatively low. This temptation shows in the desire to pay a disproportionate amount from the Station funds for people who have been called for College purposes, and to find reasons why this or that man should be paid from Station funds when he may have no qualifications for scientific work, and probably never would have been thought of as an investigator. Likewise when individuals find it difficult to get some desired apparatus for College work, it is very common for them to persuade themselves that such would be a valuable possession for the Experiment Station. These tendencies are natural, but nevertheless the use of Station funds under such interpretation would be improper.

The only safe way is to consider that these funds are trust funds for specific purposes, and that the intention of the donors has not been to expand the College as a College, but given for other purposes. It is true that in many cases these gifts add additional burdens to the College as a whole. The Adams fund, for instance, cannot reach its fullest usefulness, in fact, cannot be expended unless it is supplemented by other funds. It is not improbable that this was in the minds of Mr. Adams and his associates in preparing the bill. We cannot have the applications of science until we have the fundamental research, and research, however important it may be, is so quiet and retiring and its application may be so remote that public imagination is not appealed to, and popular support is not readily given. The applications of science are much more evident to the public mind. It is, I think, almost certain that nearly everyone will concede that the limitations of the Adams fund, and the corresponding limitations of the Hatch fund, are wise and proper.

In the interpretation of these Acts, I think it is evident that restrictions will be more and more from the standpoint of the Acts themselves. Correspondingly, expenditures made to help other needs, directly or indirectly, will be more and more excluded. In other words these two Government funds are specifically for scientific research. They are not for teaching, they are not for Institute work, they are not for the dissemination of seeds or stock, or for ordinary information, or other such purposes, and the tendency will be to interpret this more strictly and to insist if these funds are given for such purposes that the conditions must be such as to give the proper surroundings for the best results.

It may be well to summarize the finances of the Station.

These may be classed under several heads:

1. *The Government, Hatch and Adams Funds.*—The Hatch fund amounts to $15,000 per annum. This appropriation is the foundation of the Experiment Station in this, and most other States. The conditions of the fund are relatively broad, but, nevertheless, must be used for scientific investigations. The conditions fixed by Congress were accepted by the State Legislature before any of the money was turned over. In case of misappropriation of such funds the amount misused must be replaced. This appropriation is received automatically. It is available for building only to a very small extent. In other words, in order to obtain benefit from this appropriation the State or College must provide the buildings.

The Adams Fund.—The effect of this will be to double the appropriation from the U. S. It is available only for "original scientific research," as distinct from the provision to verify experiments, as in the Hatch Act. It is not available for expenses of administration, nor for printing. It must be applied within narrow limitations. This fund does not come automatically. It ceases the first of every July unless the Government shall approve the work of the Station and direct the Secretary of the Treasury to forward the money for the next year. In order to make use of this fund, buildings and other facilities must be provided by the State. The expenses of miscellaneous investigations, even though they are preliminary to Adams research, cannot be borne by the Adams fund. The conditions of this fund must be narrowly interpreted, and the result of attempting to expand them on our part is not to increase their usefulness, but will result just to the contrary. Any amount unexpended is not saved, but is lost.

There is a large amount of miscellaneous work, especially inquiries, that naturally gravitate to the Experiment Station. A great deal of miscellaneous information is called for. The expenses of Farmers' Institutes have long been prohibited; the expense of issuing information bulletins has now been excluded. It is probably only a question of time when the expenses of miscellaneous work and inquiries must be borne by other than Government funds. In other words, the tendency of the interpretation of these Acts is to confine these endowments strictly for scientific investigation. It is recognized that there must be a great deal of other work done which is of exceedingly great value, just as it is recognized that there must be buildings, and it is expected that the States will provide for these themselves.

2. *The State Board of Agriculture.*—There have been several times when the State Board has made direct appropriations to the Experiment Station. This seems perfectly proper from the Act establishing the State Board. In effect the Board, from its College funds, has made indirect appropriations, as the buildings used by

the Station are furnished, lighted and heated by the College. This has long been the practice of the College, and is probably a just one and as justified as for the College to assume the repairs and maintenance of buildings which may be gifts to the Institution to add to its general usefulness. This may be considered a burden on College funds. It undoubtedly is. On the other hand no one would deny that Senator Guggenheim, the United States, or any other giver, may offer a gift to the State or College, and attach such conditions as he sees fit. The State or College has the privilege of accepting or rejecting, but having accepted, then it is bound by them.

3. *The State by Direct Appropriation.*—The Adams Act forced the necessity of additional funds in order to make full use of it. As already stated it does not cover the expenses of popular investigations, nor does it cover the inquiries in special lines. There is great need and opportunity for this very useful work. The State has made appropriations for a number of years. The State also can give its appropriations under such conditions as it deems desirable. They are not bound by the same conditions as the Hatch and Adams Acts, but their greatest usefulness is to supplement these Acts. This in effect they do. The last legislature appropriated $53,000 for such purposes for the biennial period ending December 1, 1910.

4. *Special Sources.*—These include donations, gifts, sales and miscellaneous receipts. This has been largely during the past few years, a consequence of the other appropriations. This fund is, to some extent, the balance wheel in the Experiment Station, for upon it we must depend to tide over a temporary deficiency in other funds, or to tide over the time between December first and the date when the money appropriated by legislature becomes available.

5. *The Horse Appropriation.*—The Government appropriation ought not to be considered a special fund. It is not under our control, but is an appropriation given by the United States for the horse experiment. It, like most other gifts, involves an additional expense on our part.

CONDITION OF THE FUNDS.

The Hatch Fund.—On November 1, there had been expended $3,240, since July 1st, an excess of $1,760 over the proportional amount at a uniform rate, leaving a balance of $4,260. The bills have not been completed for December 1st, but the estimated proportional amount ahead is $2,300, and for January 1st, $2,800. This amount must be spent in the next six months in addition to the income of $6,500. As the current rate will leave an excess of $2,800 more, which means that during the next six months our expenditures must be about $5,600 more than we have spent in the past six

months. In the past six months we have spent $4,700, hence we must more than double the rate of expenditure during the coming six months, and then reduce the amount after the first of July to correspond to the proportional amount.

In the Adams fund the condition is similar. The first of December we will have expended $3,800, or an excess of $1,555 over the proportional amount, and on the first of January an excess of $1,900. In the next six months this must be expended in addition to the $6,500 income, a sum of $3,800 in addition to the present rate, or an expenditure of $3,800 more in the coming six months in addition to the present rate.

We cannot suddenly increase the rate of expenditure in either of these funds advantageously. This would be the case whether there were restrictions or not, but with the restrictions of law this cannot be used, especially the Adams fund, for the purchase of equipment, unless such equipment is specifically needed by a research which has been approved.

The condition of these two funds, therefore, indicates the amount of surplus accumulating. The Executive Committee has expressed their wish to investigate the projects and to approve them. At present none of the projects payable from the Government funds have been thus approved. If a change in the past policy is to be made it ought to be done at once, and a new policy definitely decided upon. It is more important to determine the principles than it is the details. As it is at present I want to emphasize the situation which means that there is almost sure to be an unexpended balance at the end of this fiscal year. The policy of making expenditures difficult, adds to the perplexity. It now takes from 5 to 40 days to get an authorization for expenditure through the ordinary channels. This is a cumbersome business method, and the restrictions which may be beneficial and helpful where it is necessary to prevent the expenditure of money, as in the case of the present College funds, yet add to the perplexity and annoyance of a large surplus to be taken care of, and more than that frequently prevents the beneficial use of the time which is put at our disposal by the Government funds.

I would respectfully call your attention to the need of some way of promptly securing action on proposed expenditures.

STATE APPROPRIATIONS.

The appropriations from the Legislature for the biennial period are as follows:

For Fruit and Horticultural Investigations	$10,000.00
For Potato Investigations	10,000.00
For Poultry Investigations	5,000.00
For Co-operative Horse Experiment	5,000.00

For Animal Industry	10,000.00
For Grains and Grasses	8,000.00
For Farm Machinery and Roads	5,000.00

In addition there was a special Act appropriating $2,000 for Cheyenne Wells.

The conditions of the different sections making these appropriations differ. The only safe way is to interpret the appropriation within the strict letter of the Act. Several of the appropriations include publications. The appropriation for animal investigation and for poultry do not include publication. It is possible that the Auditor will interpret the appropriation with this as implied.

The general conditions arising from State appropriations lead to various difficulties. The State fiscal year ends December 1. Under the original interpretation any unexpended balance at that date in the even numbered year, would revert to the State. The appropriations passed by Legislature do not become available until the following summer or fall. This is in addition to the uncertainty as to whether we are to receive any of it. Hence investigational work, which is necessarily continuing in its character, remains in the air from December 1st until the action of the legislature is known, or until the money becomes available. This is an undesirable situation. We cannot obtain men with the privilege of ceasing work abruptly. They are not in situation to remain for months without pay and with the possibility that they may receive none. At the beginning of the last biennial period our condition was rendered better by the interpretation of the Auditor that the unexpended balance might be transferred to the local treasurer. Hence in view of the period of delayed payments these balances were protected and were used to carry on the work until mid-summer. It is understood that the present Auditor holds that these funds must be entirely expended by December 1st of next year. If that be the case then we must alter our plans. The uncertainty concerning the money that would be received has held back this work until late in the fall. The result is that only a small part of the State appropriations have been expended. An undue amount must be expended during the coming State fiscal year. Only about $10,000 have been expended to December 1st, out of an appropriation of $53,000. There is a little more than $4,000 in bills outstanding. There is, therefore, about $38,000 to be expended in the next twelve months, or nearly four times as much as we have spent during the past twelve months. It would be far better in every way if this money could be used uniformly and on the supposition that it would tide over to July, 1911.

If that cannot be done we will need to face the situation that will arise next December. We shall have men on hand and work under way whose bills will need to be met for six months of the

year following. The funds will be gone, or cannot be used, and it may lead to the necessity of asking for a deficiency appropriation from Legislature, but in the meantime what arrangements can be made with men and for the current bills? A regular income is far more effective than irregular, spasmodic supply, such as comes from these sources.

As the best available way to meet these emergencies the Station has a special fund. There is now about $9,000 in that fund. About $2,500 of this amount is held for the expenses of the horse investigation under contract with the U. S. There is, therefore, about $6,500. From this fund we must meet various expenses that cannot be met from the Hatch or Adams funds, nor from the conditions of the State appropriations. It may also be necessary to call upon this fund to tide over the period after next November, or at least for a time. Hence this fund serves as a balance wheel of the Station funds. Into this fund go receipts from various sources. The Hatch and Adams funds are fixed by law so that receipts from sales, even though in direct consequence, cannot go back to these funds.

TABLE OF CONDITION OF FUNDS.

	Appropriated for two years.		Expended to Dec. 1, 1909.
Poultry	$ 5,000.00		$1,514.97
Animal Industry	10,000.00	($4,090 in bills)	2,909.75
Grains and Grasses	8,000.00		1,275.56
Fruit Investigation	10,000.00		4,000.00
Potato Investigation	10,000.00		2,273.86
Farm Machinery	5,000.00		?
Horse Investigation	5,000.00	(approx)	3,000.00
Cheyenne Wells	2,000.00		

The statements of expenditure are not entirely exact, as they are made before the summation in the Secretary's office. The Plant and Animal may not include all salaries.

It has been only within a few weeks that it has been certain that we should get the whole amount of the State appropriation. The conditions of the bill do not require that one-half be expended in either year, but permits an amount not exceeding a certain aggregate throughout the two years. The State appropriation supplements the conditions of the Hatch and Adams funds, and enables miscellaneous work and work which is not scientific and various inquiries to be done, which is of great use. The legislative appropriation for the continuance of the Cheyenne Wells substation, is for the sum of $2,000. To open the station and equip it with a competent man, and provide the tools and animals necessary to carry it on, would involve an expenditure of at least $5,000 per year. A sum much less than that would be ineffective and of very little value. The way which seems to me to be best calculated to

obtain results from this small amount is to arrange for direction for a few days per month from some one like Mr. J. E. Payne, or Prof. Cottrell, and thus to obtain his advice and constant supervision and have him take the essential responsibility. Then to secure a man at a much less rate than a competent superintendent would require, who should conduct the operations under the direction of the superintendent.

It would be best to have the work done by hired teams, or by teams and tools furnished by this man. That would avoid the necessity of a large expenditure for tools and teams, and their constant maintenance.

A surprisingly large number of requests come to the Experiment Station for information, and demands for various kinds of work, like analyses of soils and water. In most cases people making these requests do not realize that it would often mean several weeks work to meet their request. In many cases the people asking have a passing curiosity and would not know what to do with the results if they got them. There is, however, a certain amount of legitimate demand in this character of inquiry. It is miscellaneous work of a kind that cannot be met under the Hatch and Adams funds, because it is not a part of a direct line of investigation. We have no other choice except to refuse these requests as kindly as possible, for there has been no other fund or means provided for meeting such requests. It is unquestionable that in many cases this has led to disappointment and perhaps unfriendliness. Of a corresponding character are the hundreds of miscellaneous inquiries of all kinds that are received. Some call for considerable inquiry and all take more or less time and energy. When these requests can be answered by such information as we have they are answered as fully as possible. There is, however, a tendency on the part of the Government to interpret the Hatch and Adams funds still more strictly and where such miscellaneous work requires any notable expenditure of time and effort, to object to this being considered as one of the duties of the Experiment Station, or at least so far as chargeable to these funds. The remedy would seem to be toward meeting these from State appropriations, or from College appropriations, or possibly from special funds. In the case of such work as analysis, if we should meet all the demands that are received, our chemical force could do nothing else, and the results would be of very little consequence.

The work that clusters around the Station is of several different characters. First the research work, which is work of high character, requiring high qualifications, special preparation, and is paid from Government funds. This is work of a continuing character and may extend over a series of years. It is the backbone of

the Station work, and may be considered Station work proper.

Of a distinctly secondary character, requiring different qualifications, but as useful in its way, is the work of inquiry, inspection, the distribution of information, etc., and the spreading of useful results. This may not require the quailfications of a specialist, but it does call for more or less scientific training. This work may not be scientific, and although it receives a good deal of popular approval, it should not be confused with the more important work of the Station proper. There is a tendency for the work of inspection to cluster around the Station. The experience of the U. S. and of other Experiment Stations has shown certain principles of control and of management. The gist of these were included in a letter to the State Board of Agriculture some ten years ago, and were adopted as the principles and regulations of the Experiment Station. They have been in force ever since, and under them our work has progressed quietly and with beneficial results. The Station stands high in the scientific circles over the United States. Its work is quietly done so that in the local community it may not receive much attention. A scientific worker cannot afford to speak much of what he is going to do. He is governed entirely by facts, and thus while he might give columns in anticipation, the results may reduce to a few lines. The test of scientific work is its accuracy and its quality, not its quantity, not its public appreciation. We have reason to feel gratified with the position of our Experiment Station. It has gained the confidence of the scientific community and is gaining throughout the States because of its conservation and carefulness. A large part of its value is because it has been able to retain qualified men for a long period of time. This is partly due to the interesting questions in the State. The Director has constantly followed the policy of non-interference with the individual workers, so far as possible. To see that their lines of investigation were proper, and then to surround them with the proper conditions for work.

Undoubtedly some changes must develop. The statements before given indicate the necessity for expansion and additional work during the coming few months. If there are to be changes in the organization of the Station and the responsibility of the Director, they should be made distinctly and now.

None of the funds of the Experiment Station have caused the Committee or the Board any worry to meet deficiencies, or to meet the obligations which arise as a consequence. It is evident that there must be an increase in the work and an increase in the Station force. The requirements of the work will make an increasingly large number who are paid principally or entirely from Station funds. These men ought to be selected for their qualifications for Station work, and not as teachers, or for other qualifications. The

requirements as adopted provide that such employment shall be on the recommendation of the Director. There are many constantly selected to be paid from Station money who have not been selected in view of Station needs, and so long as such is the case the Station work is not apt to be especially creditable.

The following Bulletins have been issued during the past year:

	Edition
136—Dewberry Growing	18,000
137—Some Animal Diseases	18,000
138—Some Bacterial Diseases of Plants	18,000
139—Pruning Mature Fruit Trees	20,000
140—Strawberry Growing in Colorado	18,000
141—Grape Growing	18,000
142—Tillage, Fertilizers and Shade Crops for Orchards	20,000
143—Cabbage Growing	20,000
144—Celery Growing in Colorado	20,000
145—Dry Land Farming in Eastern Colorado	20,000
146—Raising Hogs in Colorado	20,000
147—Top Working Fruit Trees	20,000
148—Cement and Concrete Fence Posts	18,000
149—Part I. Carrying Range Steers Through the Winter. Part II. Sugar Beets for Fattening Steers	20,000
152—Two Common Orchard Mites	20,000
Press Bulletins—	
47—Field Peas in Colorado	2,500
48—San Jose Scale	5,000
49—Treatment of Seed Grain to Prevent Smut	10,000
Correspondence Circulars—	
1. Potato Notes	3,000
2. Hog Raising in Colorado	3,000
3. Orchard Management	3,000
4. Preparing Land and Trees for Orchard Planting	3,000
5. Cultural Methods for Some Common Vegetables	3,000
6. Garden Accessories and Mushroom Growing	3,000

EXCHANGES

BOOKS, PAMPHLETS, SCIENTIFIC PROCEEDINGS, ETC. 1909

Australia:
- Journal of the Department of Agriculture, Victoria.
- Annual Report of Bureau of Sugar Experiment Station, 1908-09.

Canada:
- Experimental Farm Reports, 1908.
- Report of Superintendent of Forestry.
- Report of Grain Crop and Live Stock, Prov. of Sask.
- Results obtained on Dominion Experiment Farm.
- Report of the Womens' Institutes of Province of Ontario.
- Report on Grain Crops 1908. Province of Alberta.
- Report of the Veterinary Director General Etc.
- Bulletin No. 4. Department of Canada Forestry.
- Report Department of Interior. Health of Animal Branch.
- Le Naturaliste Canadien.
- Forest Fires in Canada During 1908.
- Forest Conditions in the Crow's Nest Valley, Alberta.
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Colorado Section.
Illinois Section.
New England Section.
New Mexico Section.
Oregon Section.
Wyoming Section.

REPORT OF THE IRRIGATION ENGINEER AND METEOROLOGIST

To the Director:

The work of the past year of the Section of Irrigation Engineering and Meteorology has been largely a continuation of the work undertaken many years ago. We now have an accumulation of data in investigations connected with irrigation, and records in meteorology, and these have been carried on for a time long enough so that their reduction is the first thing of importance for the Station. The work of the year has therefore been principally directed toward reduction of this mass of data. During the same time current records have been continued and the time of Mr. Trimble has been principally directed to this end. Some of the work undertaken originally would not have been chosen had there been funds for expense in the investigations then desired to be undertaken. The aggregate fund available for work for several years was in the neighborhood of $200 for the entire year, and this forced the selection of lines where expense was small. This led to attention to some lines like seepage, where aid was obtained from various sections of the State, and in this as in several others, the results proved of far more importance than was originally anticipated. The studies thus begun needed to be carried to completion, and the facts developed in connection with this and the irrigation survey of the State, led to the facts which gave the foundation for the successful defense of the State against attack as in the second trial of the Elephant Butte case and in the Kansas-Colorado case. The claims made here would have practically suspended irrigation for the future in Colorado, and in all of the western states. While the work of the Station was only the beginning of the facts needed for the defense, yet it is safe to say that without the previous work done by the aid of the Station such defense would not have been possible. It has often been suggested and desired to take up work in the immediate application of water to crops. Some work has been done in connection with the Duty of Water. The first bulletin on this subject was issued from here, and a considerable unpublished data is now available. Yet while there is here a field of value, the conditions of development have, after all, made the establishment of some of the principles concerning the rights to water of more fundamental importance. Unless the right to use water was recognized both by law and custom, the manner of application could be of relatively little importance. With the decision of the Kansas-Colorado case in 1907, there at once followed a great activity in irrigation development, not alone in Colo-

rado but all through the West. This decision for the first time established the fact that the riparian doctrine was not to be recognized in the arid region, and diversion from streams was to be recognized by the highest court of the land. And while there are other problems troublesome enough, the fundamental one is settled in favor of the agricultural progress of the West. So far as our individual State is concerned there are other similar and analogous problems, and attempts have been made to prevent additional irrigation in Colorado in favor of new areas in lower states. For a considerable time it has been difficult or impossible to obtain government land for reservoirs in Colorado in the valley of the Rio Grande and of the Grand, under the contention that the water might be needed for regions much lower down. If the question of law be left to one side, the question becomes one of fact to be determined not from opinion but from the testimony of facts. As a side investigation a considerable data has been collected, especially on the Rio Grande during the past dozen or more years, for the problem was looming in the future.

There is now considerable unpublished work needing collation and preparation for printing. With the demands coming on me as Director of the Station, any continuity of thought or effort when here has been practically impossible. On assuming the directorship in 1899 the demands on time were insignificant, but with the increase in funds and in the complexity of Station work, the demands have become inordinate.

In an investigation requiring considerable data, there are two natural periods—one the collection of the data, the other the collation and the interpretation of it. While the accuracy of the data and the care taken is fundamental, yet the second stage is much the more difficult, and much more rarely is it done satisfactorily. The data which we now have represents the accumulation since 1888, when I first came here. The meteorological records represent one of the longest series in the country which have been made under one direction, and largely by one observer, and thus with 20 years' record, form a peculiarly valuable series. In this we were one of the first to give more attention to agricultural meteorology and to those elements important to agriculture than to meteorology in its relation to weather. We have maintained records of evaporation, of soil temperatures, of sunshine, of the energy derived from solar radiation, and these have been awaiting reduction. Because of the extent of the record, and the requests of those interested in the development of storage, and at the request of the U. S. Weather Bureau, we have given considerable attention the past year to the reduction of this series. Then, after that, it is hoped to take up some of these successively. The construction of the new building

as provided by the legislature, and availability of the special Station laboratory, we shall then have the means to make the supplementary laboratory investigations needed to complete the field observations.

The completion of the building and the laboratory facilities afforded, with the additional funds possible from the Adams fund, will make it possible to take up the lines of investigations planned and referred to in reports nearly twenty years ago, and which it has been impossible so far to put into operation to any great extent. In the present building any laboratory investigation has been out of the question, for the crowded condition has been too evident to emphasize. A second important aid will come in the provision of fireproof vaults for the preservation of records. These records have become of great value not only as parts of investigations, but for their bearing on wider state questions, and as they depend on time which has elapsed, they could never be replaced if lost or destroyed. It is hardly necessary to say that the unprotected condition has been a matter of great anxiety and much relief will be experienced with their proper security. The working up of these records becomes one of the most important matters, for now, with the accumulation of years, there is a long enough period to justify their reduction, and the possibility of death or disablement of myself would render them of little value, or at least of much less value than they should have.

In the fruitful field of the relation of water to plants, the additional laboratory facilities will now render its cultivation possible. Attempts have been made to find the qualifications desired in a helper who could give his entire time to this field, but so far not with success in view of the requirements and of the compensation that would likely be available.

During the year Mr. Trimble has continued as first assistant, having charge of the records, and Mr. G. C. Kreutzer, in computations on the records. Their work has been conscientious and valuable. Now with additional available room for office and laboratory, it will be desirable to add two more men to the staff in this line of work, one to assist in field work, one in Adams investigations.

Respectfully submitted,

L. G. CARPENTER.

REPORT OF THE CHEMIST.

To the Director:

The work of the Chemical section during the year covered by this report has been confined to the study of the occurrence of nitrates in our alkaline soils and to the subject of poisoning of fruit trees by arsenical compounds used in spraying to protect the fruit from injury by the codling moth.

We published bulletin 131 in July 1908, presenting the results of our observations up to that time and which we believed to indicate so positively that severe injury has already been done by the various arsenicals used that we were fully justified in publishing the facts as we saw them.

The matter is of such importance that we have continued our study of this subject with the view of ascertaining further facts pertaining thereto. We have had, in the prosecution of this subject, one object only in view, i. e. to discover the facts. If the arsenic does no injury, we are willing to continue to recommend its use in such strengths and its application as often as may be necessary to satisfy the orchardist; we have no prejudice against the use of arsenic on the trees, the land or the fruit, but if, as we believe, there is danger to the life of the tree, we are certainly justified in giving the people warning of the danger. I was fully satisfied when I wrote bulletin 131 that the continued use of arsenicals had in many instances caused the death of both apple and pear trees. No one has doubted for a moment that the pear blight, for instance, destroyed the pear orchards of Delta County almost completely and has done much injury elsewhere, but we have some orchards still on which we can have worm-free fruit only by, in some effectual way, protecting it against the attacks of the codling moth. Many of the remaining pear trees are very sick and many have died from some cause other than blight. The blight may have also killed some apple trees, we know such to be the fact, but there are very many apple trees sick which have been attacked by blight and while this disease has practically wiped out the pear industry of some districts, it has not been a very serious burden on our apple industry.

Winter killing has in some instances been the cause of the loss of considerable numbers of young trees particularly in cases of an early and severe freeze catching the young trees, after a period of vigorous growth with immature wood. There are also some cases in which winter injury may have been suffered by old trees. I am sure that there are such, at least I have seen trees which I was convinced had suffered from this cause.

During the past season we have lost many trees from still another cause i. e. due to the excessive fixation of nitrogen in our alkaline soils; which subject will be mentioned more fully later.

The number of sick and dying trees in our orchards, while low in percentage, aggregates a very big total of which by far the largest part is suffering from an affection which can in no way be attributed to blight, to winter killing, to the attack of fungi, or to the action of bacteria on the roots. These causes of trouble were all studied in connection with these trees by Prof. Paddock and Mr. Whipple, now Professor of Horticulture in the Montana Agricultural College.

The trouble has appeared on trees growing in all of the varieties of soil occuring with us and is not dependent upon this factor.

While I cannot discover any reason for doubting a single statement made in bulletin 131, I have, because of the importance of this matter to a very considerable portion of this state, as well as to others, spent a great deal of time in the field and have examined a great many more trees, both apple and pear to discover, if possible, some reason, if any there be, why I should modify the statements of bulletin 131, in any particular whatsoever. This work is now about completed and my results will be presented very soon, in another bulletin on this subject.

FIXATION OF NITROGEN IN OUR ALKALINE SOILS.

My work on this subject, though not appearing as an independent project under the Adams Fund, has been prosecuted as vigorously as possible. The work is so far advanced that I felt justified in presenting it at the meeting of the Society for the Promotion of Agricultural Science, held in Portland, August 17th, 1909, under the title of "Excessive Fixation of Nitrogen in our Alkaline Solis." While we have established a number of facts regarding its occurrence in the soils, in waste water mixed with drainage i. e. in the water carried by the Big Salt Wash near Fruita, in drain waters, and in waters issuing from the shales underlying irrigated mesas, there are some questions which we have not been able to study much less to solve. We have, however, proven the occurrence of very unusual amounts of nitrates at a number of places, i. e. in the San Luis Valley, in the Grand Valley, from Fruita to Palisade, in Harts Basin, at a point east of Delta, on California Mesa near Montrose, 2½ miles north of Canon City, at Rocky Ford, and other points in the Arkansas Valley and at least one occurrence in the Poudre Valley.

Professor Sackett has recently joined me in this work and has already obtained good cultures of azotobaster and established the fact of fixation beyond any doubt.

The extent to which the production of these nitrates in the soil has already advanced, in some instances, is sufficient to kill all vegetation, including many apple trees. That the nitrates are the cause of the death of the trees and other vegetation is not only indicated by the analytical results but also by experiments made on trees by the application of nitre within the feeding area of their roots when the same results were produced that we find in the trees dying within the affected areas.

Experiments were made with salt, sodic chlorid at the same time as it was thought possible that it might produce similar results but applied at the rate of five pounds to a tree set in the spring, 1907. The results produced by the application of five pounds of salt were entirely different from those produced by the application of an equal amount of nitre. The results produced by the latter were in all respects similar to those observed in the field even to the killing of the tree when a sufficient quantity was applied. This subject will be presented in a bulletin just as soon as other work will permit.

I have all the data for a short bulletin on the fodder value, heat equivalents, etc., of the Australian Salt Bush. The work on the Rio Grande water and its relation to the alkalies of the San Luis Valley is also practically completed.

The report on these subjects, i. e. The Arsenical Poisoning of Fruit Trees, The Fodder Value of the Australian Salt Bush, The Rio Grande Waters and Their Relation to the Alkalies of the San Luis Valley, and The Fixation of Nitrogen in Our Alkaline Soils, will be presented as soon as possible.

I have not yet been able to begin the study of the subject of Mountain Irrigation, including the composition and fodder value of the hays grown under this system, but it is simply held in abeyance because the other subjects have assumed such unforseen importance, especially the occurrence of the nitrates on which a very large amount of work remains to be done.

Respectfully submitted,

WM. P. HEADDEN,

Chemist.

REPORT OF ENTOMOLOGIST.

To the Director:

Dear Sir: I have the honor to submit the annual report of the Entomological Section of the Experiment Station for the year just closing.

Those taking part in the work in one way or another during the year, aside from the writer, have been Professor S. Arthur Johnson, Mr. L. C. Bragg, Mr. George. P. Weldon, Miss Miariam A. Palmer, and Mr. O. G. Babcock.

Upon the whole I am inclined to estimate the insect depredations of the year as being somewhat above the average in this state, although some of the worst insect enemies of past years, the orchard plant lice for example, have been less destructive than usual. The only outbreak of a new insect pest of importance during the year is that of the San Jose scale in a limited district upon the western slope which we hope to be able to completely control.

The various projects will be referred to under the funds from which the expenses of the work were paid.

ADAMS FUND PROJECT.

Only one line of work has been supported from the Adams Fund the past year, and that was

Project 3. Plant Lice Investigations.

A good collection of the described species of the Aphididae is very necessary for reference in carrying on this project. I was able to greatly improve the collection during a summer trip going as far east as New York and Washington. Mr. Bragg also brought back a good number of species from Kansas, Missouri, Indiana and Massachusetts that were taken during a summer vacation trip. In all, more than one hundred species of the aphids were taken and the collection very much enriched thereby.

Upon the findings of these trips one paper has been published in "Journal of Economic Entomology," and another paper has been prepared and will appear soon. A full page plate of figures accompanies each paper.

Much added information has been acquired concerning life histories of Colorado species especially in regard to the fall and spring forms of the lice and their winter habits.

A few species have been taken upon Colorado plants that seem to be new to science. These have been described and figured in their various stages of development and will be published upon from time to time in scientific journals.

Paralleling this more technical work with the Aphididae has

been a series of experiments for their control in the field which will be spoken of under expenditures from other funds.

HATCH FUND PROJECTS.

Project 1. Miscellaneous Insect Pests.

This project was proposed to enable the section to grapple with any unlooked for insect depredation that might demand attention during the year.

San Jose Scale, *Aspidiotus perniciosus.* Early last spring Mr. O. B. Whipple sent me bits of bark from an apple tree near Grand Junction that had what he believed to be this scale insect upon them. A thorough examination proved the correctness of Mr. Whipple's suspicions. Some eight or ten trees in adjacent orchards were found to be badly infested. Under the supervision of Mr. Weldon the orchards were thoroughly sprayed with lime-sulfur mixture before the leaves opened and almost a perfect clean-up of the scale resulted. Since that time Mr. Weldon has found a few contiguous orchards that are lightly infested. As State Entomologist I am undertaking to have these infested orchards thoroughly treated for the eradication of the scale before the leaves again open.

PLANT LOUSE REMEDIES.

A considerable series of tests have been made to determine the value of different insecticides for the destruction of the eggs of plant lice in early spring. A bulletin is in preparation giving the results of these tests which promise to be of considerable economic importance.

I have also made a large number of applications to determine the comparative values of different insecticide materials for the destruction of the lice after they have hatched and are feeding upon the plants. This data is also being put in shape for bulletin publication.

Project 5. Experimental Orchard.

A portion of the trees that were planted with crown galls were pulled during the summer and found to be very badly infested with galls, a few seeming to have been killed by them. The orchard has also served for Aphis experiments and for Dr. Headden's experiments with arsenical poisoning.

Project 7. The Potato Flea Beetle.

Professor Johnson has continued his work with the potato flea beetle the past summer and along with that work tested out a few arsenical preparations for the destruction of the Colorado potato beetle. Professor Johnson has a bulletin in preparation covering this work.

The beet louse, *Pemphigus betae*, with which we did some work last year, was not abundant enough in any section of the state the past summer and fall to make it seem advisable to do any work with it.

SPECIAL FUND PROJECTS.

Project 4. Codling Moth Studies.

Mr. Weldon carried through a spraying experiment in Delta County for the purpose of comparing a few important insecticides in their effects upon the apple worms; also to determine the value of rather weak arsenate of lead mixtures against this insect. The results indicate that sulfide of arsenic, a new poison for insects that was suggested by Dr. Headden for trial, was very satisfactory. In the use of arsenate of lead we were able to get apples 95% free from all worm injuries with one application using but two pounds of the poison to 100 gallons of water. I hope, before it is time to spray again for codling moth, to have a bulletin prepared giving the results of the more important work of this station with this insect.

Project 6. West Slope Field Work.

Aside from the codling moth work mentioned under project 4, Mr. Weldon carried through a series of treatments for the destruction of aphis eggs in the orchard. A freeze just as the lice began to hatch, almost completely prevented any further hatching and so made the spraying of no effect.

Mr. Weldon carried through some spraying experiments against the brown mite and red spider with excellent results. His conclusions have been published as Bulletin 152 of this station.

For a fuller report of the work done by Mr. Weldon under this project I will refer you to his report to the Director of the Experiment Station for the year.

I am accompanying this report with copies of invoice of all the station property in possession of the section on Entomology.

Very respectfully submitted,

C. P. GILLETTE.

Entomologist.

REPORT OF FIELD ENTOMOLOGIST.

STATE FRUIT INVESTIGATIONS.

To the Director:

With the exception of ten days spent at Fort Collins last December, and two weeks spent in short course work in December and January, the past three years have been confined principally to the orchards of Mesa and Delta Counties. Until the 5th day of July most of my time was spent in Delta County where several experiments were conducted. Upon being moved to Grand Junction on that date, work was immediately broadened out along the same lines that had been followed in Delta County.

The experimental work during the year has resulted in some definite conclusions, and only in one case was practically no good accomplished. For the second time an experiment to determine the effect of different insecticides upon the eggs of green apple aphis (Aphis pomi), was a failure owing to the fact that eggs did not hatch on untreated trees in orchards where experimental work was done. It might be well to mention that in certain localities, in all probability, a damp, cold spell at the time the eggs began to hatch, destroyed practically all of them, for none were seen to hatch after the bad weather came on, and trees in those orchards were not infested until late in the season when the natural increase of the few aphids that did survive began to spread to them.

Considerable experimental, as well as life history work, was done with brown mite (*Bryobia pratensis*), and red spider (*Tetranychus bimaculatus*). The work done upon these two species results in the publication of Bulletin No. 152 of the Colorado Experiment Station, entitled "Two Common Orchard Mites."

Probably the most important work of the season was directed toward the codling moth. The season has been an exceptional one as regards injury from this pest. No doubt climatic conditions were partly responsible for this fact, but in many cases neglect of the first spraying, or carelessness in its application, resulted in not only one orchard being wormy, but adjacent ones also. Where many orchards in a locality are in reality one big orchard, it is necessary for the good of all orchardists concerned, that each individual do very thorough work in spraying It is never safe to neglect the first spraying of apple trees because of a poor showing of blossoms, or from some other cause, for often trees neglected have considerable fruit upon them, and if they were not sprayed when the calyces were open the worms are bound to be plentiful, and the infestation will spread more or less, to other trees.

More time has been spent in codling moth work the past season, than in any other phase of the orchard problems, and many interesting things have been noted. In the early spring when the first spraying, at the time the calyces were open, was in progress, a great many orchards were visited, notes were taken on spraying equipment, insecticides used, its strength, thoroughness of application, etc. Many of these same orchards were visited again at picking time, and counts made of apples, to determine percentage wormy in order to get all the data possible in regard to the spraying of an orchard for the control of the codling moth. Other orchards besides those visited at spraying time, were visited in both Delta and Mesa Counties when picking was in progress, making a total of 61 orchards in which counts of apples were made and records kept. The season's observations and the experience of orchardists go to prove that the stress placed by some entomologists upon the coarse nozzle, and a high pressure is of little consequence. The theory of a driving spray is a nice one, but it is doubtful if it pays to waste, often double the amount of spray necessary, with the idea in view of driving it into the lower calyx cup. A spray such as is thrown by a good vermorel type nozzle with the coarse caps, and which collects in little globules in the calyx cup, will penetrate beneath the base of the stamens to the lower calyx cup better, in all probability, than it can be driven in with a coarse nozzle of the bordeaux type and 200 pounds pressure. The experiments recorded in this report in which a vermorel nozzle was used, and in some cases with a very low pressure, along with observations in a great number of orchards, have led me to the above conclusions.

Two and one-half pounds of arsenic of lead per 100 gallons of water is sufficient to kill codling moth larvae, as is indicated by the following average percentages of wormy fruit, from a number of orchards in each case. 2½ lbs., 21% wormy; 3 lbs., 30% wormy; 3½ lbs., 25% wormy; 4 lbs., 41% wormy; 5 lbs., 38% wormy; 6 lbs., 22% wormy. It will be noticed that the best record for the season was in orchards where only 2½ lbs. per 100 gallons of water were used. There are several things that might account for that fact. I believe it is true in most cases that the man who uses a weak insecticide tries to be very thorough, while the man who uses a strong insecticide is apt to depend too much upon its strength. While the insecticide used must be strong enough to kill the worms, it must also be applied thoroughly enough so that practically every worm that tries to enter an apple must take some of it into its stomach. Thoroughness, then is the most important factor in connection with the spraying operation, and the man who uses a weak insecticide, provided it is strong enough

to kill, and applies it until he knows that he has done a good job, is the man who is going to meet with success in controlling the codling moth. Again locality may account of the worminess of an orchard. As has already been hinted, an orchardist cannot well protect himself from the ravages of a second brood of worms, the result of a migration of moths from an adjacent orchard which has been improperly sprayed, or not sprayed at all. The question of individuality relating to the man who holds the spray rod, is one upon which too little stress is placed, and yet one of the most important of all. It is not easy to do a good job of spraying, and the man who thinks that he can do so and have a dozen other things on his mind at the same time, had better be doing something else. However, we may account for the fact that 2½ pounds of arsenate of lead per 100 gallons of water gave even better results in orchards where investigations were made, than higher strengths, we may feel sure, at least, that it was plenty to do the work satisfactorily.

In certain localities one spraying is all that is necessary to control the codling moth. In Delta County a great many orchards were sprayed only once. The percentages of wormy fruit from these orchards which were visited, shows that much better results were attained than in orchards of other sections sprayed two, three, four, or five times. It is argued by some that worms were very scarce in Delta County and that there would not have been much trouble from them had orchards been left unsprayed. Several unsprayed orchards were found, and one of them which was visited had, by actual count of apples from a Ben Davis tree, 95% of its fruit wormy, while many orchards in the same locality, sprayed only once, while the calyces were open, had only 6% wormy. In the Grand Valley there seems to be no doubt but that every spraying after the third was thrown away. The average percentage of worminess in orchards sprayed two, three, four or five times was respectively 17, 35, 36, 33 and 44. The difference of 3% between orchards sprayed three and four times is not enough so that any benefit could be claimed for the fourth spray.

The records of individual orchards show that three sprayings did the work as well, in most cases, as four. The two spraying records as well as the one, are not considered here, for in the case of the former most of the orchards visited were in Delta County, and in the case of the latter all of them were. That every spraying after the third was thrown away in the Grand Valley seems almost positive, and it is doubtful if it is necessary to spray more than twice if the first spraying is done at the right time, and with thoroughness. In order that two sprayings may be successful in controlling the codling moth, it is necessary that everyone spray, not

only certain varieties that bid fair to have a good crop, but everything in the shape of an apple tree that blossoms at all.

The most striking thing in connection with the record of unsprayed trees is the large percentage of apples wormy in the calyx end. An orchard sprayed thoroughly at the time when the calyces are open should have very few calyx worms at the end of the season. A calyx cup well filled with arsenic in May is a death trap for every worm that tries to enter that way in August or September.

The experiment recorded in this report was considered a failure until the second brood of worms came on in August, yet several trees gave the remarkable record of not a single calyx worm. The total percentage of calyx worms in apples of trees unsprayed was 69, while in those of sprayed trees the total percentage was only 11.

EXPERIMENTS IN ORCHARD OF J. B. HART, ECKART.

This orchard was chosen for the experiment because of the good prospects for a heavy crop, the convenient size of the trees, and because of the fact that there were a great many worms in the apples that the trees produced last season. A block of 215 Ben Davis trees were selected from the orchard, 202 were sprayed and 13 were left unsprayed for checks. Following is a record of insecticides used and the percentage of wormy fruit in each case. In figuring percentages any apple having a mark in the skin made by a codling moth larvæ was considered wormy:

"Black Leaf," 1 part to 50 parts water	23%	wormy
Sulfate of nicotine, 10 oz. to 50 gals. water	30%	wormy
Sulfate of nicotine, 12 oz. to 50 gals. water	27%	wormy
Lime, 25 lbs. to 50 gals. water	41%	wormy
Unsprayed trees	41%	wormy
Sulphide of arsenic, 1 gal. to 50 gals. water	7%	wormy
Sulphide of arsenic, ½ gal. to 50 gals. water	6%	wormy
Arsenate of lead, 2 lbs. per 100 gals. water	5%	wormy
Arsenate of lead, 3 lbs. per 100 gals. water	4%	wormy
Arsenate of lead, 4 lbs. per 100 gals. water	4%	wormy

The number of calyx worms in apples of arsenic sprayed trees ranged from 0 to 7. In apples of trees that were not sprayed, or which were sprayed with an insecticide that was ineffective, the number of calyx worms ranged from 98 to 481.

The following conclusions may be drawn from the experiment:

1. Nicotine preparations are of very little value, if any, in controlling the codling moth.

2. Sulphide of arsenic is practically as good as arsenate of lead, and further experiments will probably show that it is entirely as good.

3. Two pounds of arsenate of lead per 100 gallons of water is enough, when carefully weighed and applied, to do excellent work.

4. It is possible to keep practically all the worms from entering the calyx for the entire season by a spray at the time the calyx is open.

5. A vermorel type nozzle is just as efficient as a bordeaux type, and does not waste so much of the spray. A low pressure is practically as good as a high, provided enough pains are taken to do thorough work. It is easier, however, to do thorough work with a high pressure machine.

6. One spraying given at the time the calyx is open is sufficient in certain localities, at least, to control the codling moth.

SAN JOSE SCALE.

This pest was found by Mr. O. B. Whipple in two adjacent orchards early last spring. Both orchards were thoroughly treated with home prepared lime and sulphur, using 20 pounds of lime and 15 pounds of sulphur to 50 gallons of water. It is gratifying to note that the scale was practically exterminated from these two orchards. It had, however, previously spread to several others in the vicinity, and up to the present time a total of 15 infested orchards have been found. An effort will be made to exterminate it, or at least to check its spread.

Respectfully submitted,

Grand Junction, Colorado,
December 1, 1909.

GEORGE P. WELDON,
Field Entomologist.

REPORT OF HORTICULTURIST AND POTATO INVESTIGATIONS.

To the Director:

The work in Experiment Station has been somewhat broken up owing to the numerous changes in the Horticultural section.

Until August 1st my time was employed in investigating the potato industry. Since that time so much of my time has been devoted to class and executive work in the college department of horticulture that little time could be given to the potato investigation. Mr. C. L. Fitch was employed October 15, 1909, as assistant to carry on the potato investigation. My policy for the future work of horticultural investigation is to follow up and complete the projects previously outlined as far as possible. Some of these projects have been completed and the results published in bulletins. This schedule with its present status is as follows:

The Raspberry Industry. Not yet worked up.

Tomato Blight. Some work was done on this subject the past summer but no definite results were obtained as there was little blight in the fields. It has been quite definitely determined that this trouble is caused by a Fusarium and that when clean soil is used for the seed bed, clean tools are used in handling, and the plants are set in uninfected soil the plants are not seriously troubled with this disease. The disease is evidently much worse some years than others. This investigation should be carried on as the tomato growing industry is becoming more important in Colorado each year.

Raspberry Yellows or Raspberry Blight. The work done with this disease indicates that this disease is caused by a fungus, but no remedy has as yet been discovered. The investigation should be continued.

The orchard, plant, location, site and soil for orchard investigations, history and development of the fruit industry in Colorado, etc., are in the hands of the West Slope Fruit Investigation.

Cold storage of Vegetables has not been sufficiently investigated to report.

The Cabbage Industry of Colorado has been written up and published as a bulletin.

The Strawberry Industry has also been written up and published.

Black rot of strawberries is a disease (probably fungus) that is causing much trouble and the investigation should be continued.

The potato industry investigation has been carried on along practically the same lines as in previous years except that owing to the increased appropriation more demonstration work has been attempted than in previous years.

A tract of ten acres of land at Greeley was rented from Sanbourn and Houston and planted to potatoes. The object of this work was partly to compare varieties of potatoes in hopes of obtaining a variety that might be more reliable in the Greeley district than those now grown and also for a study of seed of the standard variety (Pearl) from different sources. The crop was not a success owing to the poor season and the ravages of the potato beetle. Some valuable data was secured however as the value of seed from different places.

A quantity of seed potatoes from Fort Collins was sent to Middle Park to determine the advisibility of growing potatoes in that section of the state. Although this seed was planted late the resulting yield of potatoes was good (about 100 sacks per acre), and the appearance and quality of the potatoes was unexcelled. About five acres of potatoes were planted on the horticultural grounds of the college.

The object of this plot was to have material for disease study and to test different types of seed, seed treatment for scab, etc. A fair crop was obtained although grasshoppers caused serious injury.

Another plot of potatoes was planted at Eastonville, Colo., in co-operation with the Russel Gates Mercantile Co. The object of this was to study the seed potato proposition of the "Arkansas Divide" country. A very poor crop was obtained. Co-operative work with potatoes was also carried on in other parts of the state for the purpose of obtaining information as to the status of the industry in the different sections.

During the year much time has been devoted to institute work. This work was largely for the purpose of promoting the potato industry and better cultural methods, etc.

Respectfully submitted,

E. R. BENNETT.

Horticulturist.

REPORT OF FIELD HORTICULTURIST.

STATE FRUIT INVESTIGATIONS.

To the Director:

The following report covers the work done from July 15th, 1909, to November 1st, of the same year. The work has been more along the line of investigating and studying orchard conditions, so that by another year work can be done on an experimental basis on subjects of importance to the orchardists of this state. The work this summer has been carried on with the best of harmony with the growers, and at all times they were willing to co-operate in the work. All suggestions have been as conservative as possible, as it was thought better not to give any exact or detailed advice, until the conditions could be better studied, although all of the help possible on general lines was given. A great many orchards were visited, but there were quite a few that it was impossible to get into on account of lack of time, although all places on request were visited.

A good deal of time was spent with Mr. G. P. Weldon, the Field Entomologist, and Mr. H. A. Richardson, the Delta County Horticultural Inspector, who were very kind in helping me to get acquainted with different orchardists and orchard conditions.

The approved lines of work were such that at least for the most part could not be carried on at the time I arrived. They were the following:

1. Study of Fruit Buds.
2. Notes on Season of Bloom.
3. Crossing Apples.

STUDY OF FRUIT BUDS.

Some work on Study of Fruit Buds was done by Prof. O. B. Whipple, and embodied in the Bulletin No. 139, "Pruning Mature Fruit Trees," and as he suggested: "It may be well to continue the work along this line, not only to determine how different varieties bear their fruit, but to determine how soil conditions or cultural methods influence a fruit bearing habit." Some notes have been taken on the subject this summer, but more data from time to time will have to be gathered before any definite conclusions can be made, telling how soil or cultural methods influence a fruit bearing habit.

NOTES ON SEASON OF BLOOM.

Regarding this, Prof. O. B. Whipple made the following statements: "The object of this work has been to determine what

varieties are adapted to interplanting, with the idea of providing for cross fertilization. The relative blooming season of varieties has been found to vary considerable from year to year. So far, the notes have shown that with few exceptions the different varieties of apple bloom near enough together to insure cross fertilization. Practically all varieties of pear bloom almost simultaneously. These observations may be carried on with other work, and should be continued for some years to determine whether the conclusions reached with the limited data at hand are reliable.

CROSSING PEARS.

The object of this was to determine what varieties were self sterile, and what varieties were adapted to cross fertilization, the main object of this was to produce a good seedless variety. Prof. O. B. Whipple says that very little has been accomplished, on account of the losses of the fruit crop by frost, and I came too late to do anything with it this year.

PLANT DISEASES.

In general the orchards are in very good condition as far as plant diseases are concerned. There is some trouble from arsenical poisoning, and it is feared that the trouble is on the increase. *

APPLE DISEASES.

Alternaria.—This was noticed working on apples which had been badly injured from hail. The area that was damaged by hail was small. It might be well to add, in this connection, that the Ben Davis and Jonathan were damaged the worst by hail (Sept. 1) and the Rome Beauty, least.

Mildew.—A powdery mildew of the apple was found to a limited extent on top worked Rome Beauty. This was controlled by half strength Bordeaux.

Blight.—Except in a few cases, blight has not done much harm this year. The twig or spur blight was controlled by picking off the affected parts and burning them. Some damage was done by what was supposed to be trunk blight. One case was found where about twenty Ben Davis trees were nearly girdled. These trees were sixteen to eighteen years old, and except for the injured trunk seem to be in good condition. The affected bark had been cut away, and the wound washed with a weak solution of corrosive sublimate (1 to 2,000). Close watch will be kept on these trees to see what develops.

Rosette.—This trouble, although often found in apple trees, is also found affecting other trees, such as pears and plums. So far it appears that this trouble is due to soil conditions, the tree

*** Dr. Headden is still working on Arsenical Poisoning, and also on the trouble that is causing the "brown" leaf.**

showing a lack of proper food material, as is shown by the growth of the branches. It will be generally noticed that where rosette appears that each present year's growth is less than the year before. It is believed that with proper cultivation and the raising of a leguminous crop, which later plow under, that this trouble to a great extent at least can be eradicated.

Winter Injury.—Quite a number of young apple trees were frozen at the ground line during the last winter. Two year old Rome Beauty seemed to be affected the worst. For example, in an orchard where Rome Beauty, Jonathan and Gano were planted, and where all of them showed the effect of freezing at the ground line, causing the bark to bridge up as though it had been slit for an inch or so with a knife in two or three places around the tree, the Jonathan and Gano had been able to heal over, but the Rome Beauty in most cases had dried out, causing a girdle. These trees had all been headed too high, and had been sun scalded on the southwest side. In the part of the orchard where a garden had been grown the summer before, and where weeds had been allowed to grow, the trees escaped injury. In another orchard under about the same conditions, the trees were protected by a wire netting, twelve inches high, placed around the trunks, as very few showed any signs of ground line freezing or sun scald.

Yellow Leaves.—Quite a few small yellow leaves were noticed on apple trees. They were immature, rather thick and from one-fourth to one-half the natural size; were always found to be the first leaves that came out, and were undoubtedly injured by late spring frost.

Frost Marked Apples.—Many of the apples this year showed frost marks, which was generally showed as a russeting around the blossom end, and in some cases the calyx were frozen off without injuring the apple, as far as maturing it was concerned.

PEACH DISEASES.

Peach Mildew.—But one orchard was found which was badly affected with this trouble. The worst affected trees were dug out and burned. The rest of the orchard will be watched to see that the mildew is controlled either by Bordeaux or self boiled lime-sulphur.

Brown or Pustlar Spot.—This trouble was first brought to notice in September, as appearing principally on Albertas, it was later found on seedlings. In some places, there was considerable loss and the trouble seems to be in a good many localities, although, in general, there has not been so far much trouble from it, but because it appeared to some extent in an orchard last year and was worse this year, it has been thought best to do some experimental

work on it during another year. Self boiled lime-sulphur 10-10-50, might prove a good remedy for this trouble.

Gummosis.—Quite a number of peach trees have been found dying from a girdled condition of the trunk at the ground line. Trees of different ages are affected alike with gummy substance being exuded. On August 26th, some of this substance was inoculated in the trunk at the ground line of a healthy tree. On September 26th, the wounds had dried up and from appearance it looked as if the trouble could not be transmitted by inoculation. Prof. Sackett was unable to find any disease germs in specimens sent to him. So the trouble may be only mechanical in nature, and might be caused by winter injury.

Gummy Peaches.—Quite a few of these have been noticed this summer, and careful examination by Prof. Longyear showed that not all of the trouble was caused by the peach twig borer, as many people supposed, but by the spring cold weather which killed the embryo of the seed but did no injury to the fleshy part of the peach.

Yellow Peach Leaves.—For the most part, it is believed that when leaves turn yellow early in the season that it is due often to early maturity. This is true where the yellow leaves are the oldest ones and have been shaded and robbed from plant food by the younger and more recent growth of leaves. Peach trees of early varieties often turn and lose their leaves in September. Especially is this true of trees over five years of age, and where they have not been allowed much water, and also where they are planted rather close together.

PEARS.

Outside of the pear blight and trees occasionally killed by arsenical poisoning, the pear trees seem to be quite free of disease. The pear blight has been pretty well controlled by picking and burning the affected parts. A few trees have been killed by what appeared to be leaf blight; the cause of this is not known.

CHERRIES.

Cherry trees are quite free from plant diseases. Some trees have been dying, but this was due undoubtedly to shallow planting and shallow rooting, the latter caused by lack of proper cultivation, such as deep plowing, etc.

SHADE CROPS.

This is one of the most important, as well as the least understood of anything in the management of a bearing orchard. That something must be done to reestablish and enrich our orchard soil, the orchardists are coming to realize, but just what to plant and how to handle has not been worked out. Some are trying one

thing and some another, but no systematic rotation has been adopted. So far as has been observed, alfalfa is as good or even better than anything, as it has given better results. The greatest objection being that when allowed to grow too long, it is apt to seed itself around and near the trunks of the trees, and when old is hard to plow under. The greatest objection to clover is that, unless sewed early on the snow or when the ground is in a damp condition, it takes too much irrigating to get it started, especially is this true for stone fruits. In some cases, field peas and cow peas might prove satisfactory, but it is feared they would lack the lasting quality as compared with some of the others. The winter hairy vetch has been recommended, but the seed is hard to obtain It is quite obvious from the foregoing that an extended experiment along this line is desirable.

THINNING.

Although this is practiced to some small extent, it is not done as much as should be. Some work along this line on apples was done, with results that showed two things, viz:

1. That the trees held their load up better and did without the use of props.

2. The fruit was of better quality, both in size and color than the checks. Another reason for thinning is the effect it has on the bloom of the following year, i. e. to see if thinning will do away with the so called "off year" in bearing.

ORCHARD HEATING.

The data received on this subject has been reported on in a former report.

Respectfully submitted,

Delta, Colorado,
December 1, 1909.

R. S. HERRICK,
Field Horticulturist.

REPORT OF THE BOTANIST.

To the Director:

Dear Sir: I herewith report the work which has come within my province during the last year.

A large portion of my time is taken up in teaching. During the past year I have taught each of the seven courses given under the head of botany. In addition to this some special students have taken work with me which has further reduced my time for station work.

The usual lines of correspondence, seed testing and identification of plants, particularly weeds, have been attended to.

The principal project for investigation during the past season has been that of studying the black root trouble of the strawberry. The resignation of Professor Paddock and the placing of the department of horticulture in my hands as acting head took all of my time and strength up to the time of the appointment of Professor Bennett to the chair of horticulture. Consequently almost no work was done during that period along this line.

Early in the season samples of smutted barley were received from the San Luis Valley for examination and germination tests to determine the strengths of formalin treatments which bald barley could endure. These experiments were outlined by myself and conducted by Mr. Floyd B. Paddock under my supervision. Some field experiments were made on a small scale to determine the relative effectiveness of different strengths. The results of the germination tests were published in "News Notes" early in the season. The results of the field tests are still on hand and will be published through the same channel in the near future.

Some work was also undertaken during the past summer on the eradication of dandelions by means of iron sulphate. Several small plats were laid out in one of the worst infested parts of the campus and applications were made at varying periods during the latter part of the season. The results are very encouraging and demonstrate the practicability of this means of eradicating dandelions from lawns. The data obtained from these experiments will also be published either in the form of a press bulletin or by means of the "News Notes."

The manager of the American Beet Sugar Co., at Rocky Ford, inquired last spring for someone who could make an extensive collection of the weeds and native plants that occur in beet fields, together with many of the native grasses. Mr. George Smith, one of our regular students, was secured for this work and was paid

a regular salary by this company for doing the work which was under my personal supervision. A fine collection of 500 specimens was obtained. These plants must all be inspected by myself before they are ready to forward to the sugar company.

The work of teaching during the present fall term has been unusually heavy for the botanist and thus far but little time has been found for the continuance of investigations with the strawberry black root. Attempts made to grow seedlings under sterile conditions have so far proven unsuccessful. This is work which should have the undivided attention through an extended period in order to insure satisfactory results. However, the work will be carried on to the best extent possible under the circumstances.

Very respectfully submitted,

B. O. LONGYEAR,
Botanist.

REPORT OF THE VETERINARIAN.

To the Director:

For the first time in the history of the Agricultural College the veterinary section of the experiment station is equipped for investigation and experiment in animal diseases. We are now very well provided with laboratories and necessary facilities for this work. We are fortunate in having available for this work a pathologist of national repute, in Dr. B. F. Kaupp, who came to us from Kansas City Veterinary College one year ago. In the investigation of animal diseases, pathology ranks second to none, as it is concerned with the structural alterations of the organisms which may result from abnormal conditions. In the study of these abnormal conditions the work of the pathologist is fundamental and final.

I wish to strongly recommend that Dr. Kaupp be placed on the experiment station staff, as pathologist. This recommendation carries with it no monetary consideration, is purely honorary, and will entitle him to receive bulletins from experiment stations, to sit in conference with station workers, and all together will in a large measure reward him for one fourth of his time, which he naturally feels that he is giving gratuitously under present conditions.

In addition to work which we are now doing with Necrotic Stomatitis in hogs, and lip ulceration in sheep, we have been called upon to investigate outbreaks of rabies, blackleg, infectious anemia, forage poisoning in horses, and infectious diseases of poultry. These latter conditions, however, I fully appreciate, belonging properly to the College and not the Experiment Station, as they have not been undertaken from the standpoint of research or investigation further than to diagnose and suggest appropriate prophylactic and remedial measures.

LOCO.

The loco weed investigation co-operative with the Department of Agriculture, has after four years, been terminated. The animals surviving, have been sold and the money turned back into the station. The experiment is supposed to have proven beyond question that the so-called loco weeds are responsible for the locoed condition of live stock on the open range, and that the salt barium found in the plant is the stiologic factor.

NECROTIC STOMATITIS.

Necrotic Stomatitis (sore mouth disease) of hogs has for two winters preceding this, been unquestionably the most important disease affecting live stock in the state. Important because of its

wide distribution throughout the state, and the financial loss which it has entailed. It has been definitely proven that the micro-organism, *bacillus necrophorus* is the causitive factor. This germ has evinced a degree of virulency and an economic importance in the western states of America, that has not been reported elsewhere. Not only is it responsible for the disease in hogs mentioned, but is known to be the cause of the so-called diphtheria of calves, lip and leg disease of sheep, and often gains entrance to the tissues of the body through abrasions, causing deep seated necretic sores that have little tendency to heal. At the present time, the necrotic stomatitis in hogs is not as prevalent throughout the state as it has been for the past two years. Another manifestation of the disease, however, known as "lip and leg ulceration of sheep" has made its appearance in Wyoming and seriously hampered the sheep feeding industry of northern Colorado as well as a sourse of financial loss elsewhere. The federal authorities have quarantined infected districts and interstate traffic of sheep affected with this disease, or from districts where this disease is known to exist, has been stopped. The crux of the whole proposition is that the Colorado sheep feeders claim that their sheep have been held in transis, entailing much financial loss and great inconvenience, because of a mistaken impression on the part of federal inspectors, that a perfectly harmless sore lip condition of sheep caused from change of feed, was the real infectious condition known as "lip and leg" disease.

The relation of these two diseases is according to the report of sheep feeders, a matter of much importance as affecting the future of this industry in Colorado, and it is by their request that we have undertaken to determine the relation of the sore lip condition of lambs, when they first arrive at the feed lots, and the lip and leg disease of sheep in Wyoming.

This investigation is well under way but as yet does not warrant a statement as to conclusions

We are under obigation to Senator W. A. Drake and others for the loan of lambs to conduct inoculation experiments.

INFECTIOUS ANEMIA.

This disease of horses was reported three years ago, as existing east of Colorado Springs, where it was generally known as the "no name disease." Very little was known of the disease at that time, although it had been reported from eastern Canada and a few other places, still its identity had not been determined in this state. Since that time it has assumed a degree of importance that has claimed the attention of prominent scientists of the western continent and the Department of Agriculture have it

under investigation. Because others better prepared to prosecute such an investigation have taken it up we have done nothing beyond taking field notes, and holding a few autopsies.

This much seems to have been definitely determined: That it is caused by a non filterable, ultra microscopic virus, and while it is not contagious by ordinary contact of animals, yet it is proven to be infectious and the virus exists in the blood. The mortality appears to be fully 90% and at present no satisfactory treatment has been found.

Respectfully submitted,

GEO. H. GLOVER,
Veterinarian.

REPORT OF THE BACTERIOLOGIST.

To the Director:

I beg to submit herewith the annual report of the bacteriological section of the experiment station for the year 1909.

Our investigations on the bacterial disease of alfalfa have been continued throughout the year. The causal micro-organism has been isolated repeatedly from diseased field material and has been reinoculated onto greenhouse stock where the disease has been produced artificially in 100% of the inoculations with all the typical symptoms found in the field where natural infection has occurred. The morphological and cultural studies of the organism have been completed in the laboratory and are now being assembled for publication as a technical bulletin.

The results from our alfalfa plats at Gypsum, Colorado, where we have been endeavoring to secure a disease resistant variety, have been disappointing owing to the fact that the one or two strains, which one year ago appeared to be totally resistant, showed the disease this year. Field observations this season seem to indicate that immunity to the disease is closely related to resistance to late spring freezing. Without exception, those plants which were severely injured by the late frost were the first to show the disease and were the worst infected later in the season, while, on the other hand, those varieties which grew from hardy stock and which suffered only slightly from the frost were more nearly free from the infection. Next year we shall endeavor to determine whether this relation between disease resistance and frost resistance is a constant one, and if it proves to be such, we shall then attempt to combat the disease by securing frost resistant varieties. As a means of prevention, we shall try early clipping as soon as we are reasonably certain that there will be no more danger from frost.

A second line of investigation, embracing Bacteriological Studies of Alkali Soils, has been taken up recently. It is intended to make this a branch of the general alkali project, some phases of which have been taken up already by other members of the station. The work as outlined at present will cover a period of at least five years and is to include an intensive study of the bacteria of our alkali soils with special reference to their physiological functions as affected by agricultural practices.

Some information upon the nitrogen fixing power of certain soils was very pertinent to a current investigation of the chemical section and consequently we have taken up this division of our soil research first. Our work at present is of a preliminary nature

since we wish to ascertain merely the presence or absence of the nitrogen fixing germs, and as the inoculation of a culture solution with a crude soil extract is the most direct means to the desired end, we have employed this method exclusively. We have been able to demonstrate in this way the occurrence of the genus azobacter in soils from two different localities out of the three which we have examined thus far.

During the coming year, we expect to increase the number of localities under study and to determine by cultural methods the exact species of azobacter present, and to note especially whether we have any undescribed species at work. If any new forms should be found, it will be very desirable to study their nitrogen fixing power both in pure culture and when associated with other micro-organisms since the only way in which we can reach any safe conclusions regarding the microbic activities in so complex a substance as a soil, is through the study of the pure culture and subsequent known combinations of pure cultures.

A very valuable and necessary addition has been made to our equipment in the form of a microphotographic camera by means of which we are now able to make permanent records of important transient phenomena.

Bulletin No. 138, "Some Bacterial Diseases of Plants," a popular treatise upon some of the most common bacterial diseases of plants, has been published during the past year.

Very respectfully submitted,

WALTER G. SACKETT,
Bacteriologist.

REPORT OF HORSE BREEDING INVESTIGATION.

To the Director:

Dear Sir: I beg to submit the following annual report of the horse breeding investigation work as conducted by the Colorado Experiment Station in co-operation with the United States Department of Agriculture. I have appended in this report a detailed record summary of the various animals connected with the station, covering the entire period of the experiment.

CONDITION OF EXPERIMENT.

The horse breeding work is progressing very nicely, the 1909 crop of foals being an unusual lot of fine youngsters. The percentage of foals gotten at this station this year was 75.9 per cent of the number of mares bred. This is a very high percentage and taking into consideration the quality of the colts, the results for the season are exceptionally gratifying.

The brood mares are maintained on pasture the major portion of the year, although during the winter months an allowance of upland hay is fed daily to keep them up in condition. The younger maturing animals are kept in paddocks at the stables and fed an allowance of alfalfa hay and oats. The younger stallions are trained to a limited amount of work in harness as two-year-olds, but as our force of men at the barns is limited, time will not permit of the handling of any filly foals whatever.

IMPROVEMENTS.

The improvements at the station during the past year have been limited. Two paddock sheds were built at an approximate expenditure of two hundred and fifty dollars; one hundred feet of fire hose was obtained, giving a connection with the water hydrant previously installed. The painting of the buildings and fences at the station has added greatly to the appearance of the grounds. No recommendations for further improvements are suggested at this time, as the station is well equipped for the winter.

OUTLINE OF POLICY.

The Government Board of Survey, consisting of Mr. Geo. M. Rommel, chairman; Professor C. F. Curtiss, and the Expert-in-Charge of the station met August 23, 1909 and inspected the station. The following is taken from the report to the Secretary of Agriculture concerning the disposition to be made of young stallions matured in the experiment.

"There are, in the stud at present, three promising young

stallions that we desire to test, with a view to determining their value for breeding purposes. The stallions referred to are: Three year old bay stallion, Albion, by Carmon; dam Arizona. Three year old bay stallion, Alba, by Carmon; dam, Washington. Two year old bay stallion, Balfour, by Carmon; dam, Dakota.

"In order to test these and other young stallions that may be produced later, we recommend the adoption of the following policy:

"First. Retain in the stud at Fort Collins, for limited service in the stud and for public service at a moderate fee, such stallions for a period of two years or longer and reserve decision as to the final disposition of such stallions until they have been tried in the manner indicated.

"Second. If the number of stallions to be tested in this manner should exceed the number that can be advantageously retained in the stud at Fort Collins, we recommend that a part of the stallions be placed in the hands of good and responsible breeders, or experiment stations, in communities where they will be mated with suitable mares at a moderate fee, for a period of two years or longer, on terms to be agreed upon by written contract. The ownership of such stallions to remain as at present, and the stallions placed for public service in this manner to be subject to withdrawal by the authorities in charge of the experiment at the end of the breeding season, or at any time during the breeding season, or at other times, as in case of neglect or improper care, or for any other good reason."

The above policy as outlined in the report was approved by the Secretary of Agriculture along with the full report of the board.

DISPOSAL OF SURPLUS ANIMALS.

During the past year twenty-one animals have been eliminated from the station by public auction, fifteen of this number being station property. The following report is appended showing the disposition made of each station animal sold:

In addition to the above sales the two colts, Ben Hur and Colman, by Carmon; dam, Georgia, were sold to the college farm for driving purposes.

STUD RECORD SUMMARY.

A brief, history, produce record, and breeding of the various animals in the stud is given below. The animals numbered from 1 to 30 inclusive constitute the original herd and those purchased later or donated to the experiment. The mares numbered, 31-32-33-34-35-36-38, were bred and matured at the experiment station, being placed in the stud during the season of 1908. These mares were shipped to the United States' Morgan Horse Farm, Middle-

bury, Vermont, in September to be bred to the Government Morgan stallion, General Gates. They will be retained at that station until next season.

STALLION SERVICE RECORD.

Stud No. 1. Carmon b. s., 32917.

Bred by Norman J. Colman, St. Louis, Mo., foaled 1895; height 16 hands; weight 1250 pounds; sire, Carnagie 8405, by Robert McGregor 647; dam, Monitor Maid, by Monitor 1327; second dam, Clara C. by Seth Warner 281.

Purchased February 1, 1905. At head of stud.

SERVICE RECORD OF CARMON, 1905-1909.

	Station Mares		Outside Mares						
Year	Bred	Foals	Bred	Foals	Total No. Mares Bred Once	Total No. Mares Returned	Total No. Mares Bred	Foals Got	Per centage Foals Got
1905	19	15	10	7	11	18	29	22	75.76
1906	21	17	19	7	....	.....	40	24	60.00
1907	21	14	24	12	22	23	45	26	57.78
1908	22	16*	37	27	39	20	59	43	72.88
1909	18	....	26	.....	22	22	44	.....	.....

* One still born. Four died at birth, leaving total of eleven thrifty foals.

Date Sold 1909	Foal Record No.	Name of Animal	Dam	Purchaser	Price
1-16	13	Appollo	California	L. Kern, Fort Collins	$146 00
1 16	14	Arden	Illinois	C. Zimmerman, Fort Collins	70.00
1-16	21	Barbara	Michigan	C. H Barkley, Fort Collins	68.00
1 16	29	Boralma	Minnesota	Smith Karnes, Fort Collins	160.00
1-16	30	Brownie	Illinois	Alex Nelson, Fort Collins	66.00
1-16	43	Carrie	Minnesota	G. W. Boston, Fort Collins	100.00
1 16	42	Curtiss	Florida	S. H. Pierson, Denver, Colo.	56.00
1-16	46	Colomel	Monella	S H. Pierson, Denver. Colo.	52.50
9 26	18	Amelia	Idaho	C. Zimmerman, Fort Collins	130.00
11 20	10	Archie	Dakota	F. J. Fitzpatrick, Fort Collins	175.00

DATE SOLD 1909	FOAL RECORD NO.	NAME OF ANIMAL	DAM	PURCHASER	PRICE
11 20	37	Carlyle	Dakota	John Mumm, Wellington, Colo.	$ 80 00
11-20	20	Beulah	Virginia	D. N. Fee, Fort Collins	90.00
11-20	35	Cynthiana	Virginia	D. N. Fee, Fort Collins	135.00
11-20	22	Bonnie Boy	Bonnie Iowa	S. J. King, Fort Collins	145.00
11-20	47	Castleman	Mambrina	Geo. L. Gross, Ft. Collins R.F.D 1	100 00

Gross proceeds of sales during 1909, $1,575.50.

Stud No. 2. Washington, ch. m.

Bred by Mr. Rodgers, Lebanon, Ohio, foaled 1899; height 16 hands ½ inch; weight 1200 pounds; sire, C. H. Pinchell 25226; dam, by Clermont by Red Wilkes 1749. Purchased February 1905.

1906—March 23, b. s. Alva, foal No. 5, by Carmon 32917. Placed in stud in 1909.

1907—March 18, ch. c. by Carmon 32917 (died at birth). Martha Washington died August 12, 1907 from a ruptured blood vessel in the chest cavity.

Stud No. 3. Kentucky, br. m.

Bred by John J. Hughes, Lexington, Kentucky. Height 16 hands; weight 1215 pounds; sire, Harrison Chief 1606 (S); dam, by Whirlwind, by Indian Chief 1718 (S). Purchased February 1905.

1905—February 27, b. f. Anita, foal No. 6, by Carmon 32917.

1907—May 20, br. f. Belva, foal No. 19, by Carmon 32917.

1908—Bred to Carmon 32917. (Not in foal).

1909—September 11, b. c. Dewey, foal No. 66, by Carmon. 32917.

Stud No. 4. Virginia, b. m.

Height 15:3½ hands; weight 1225 pounds. Purchased Feb., 1905.

1906—April 4, b. f. Arba, foal No. 7, by Carmon 32917.

1907—May 13, ch. f. Beulah, foal No. 20, by Carmon 32917. (Sold November 20, to D. N. Fee, Fort Collins, Colorado).

1908—May 16, ch. f. Cynthiana, foal No. 35, by Caromn 32917. (Sold November 20, 1909, to D. N. Fee, Fort Collins, Colorado).

1909—Not in foal.

Stud No. 5. Michigan, b. m.

Bred by C. J. Monroe, Bangor, Michigan. Height 16 hands; weight 1100 pounds; sire, Prince L 5947; dam, by Temperance 6819. Purchased February 1905.

1906—March 21, b. f. Ada, foal No. 8, by Carmon 32917.

1907—September 12, b. f. Barbara, foal No. 21, by Carmon 32917. (Sold January 16, 1909, to C. H. Barthy, Fort Collins, Colo.).

1908—September, b. c. Confusion, foal No. 36, by Carmon 32917. (Died October 14, 1909.)

1909—Not in foal.

Stud No. 6. Iowa, gr. m.

Bred by Mr. Chas. Haskins, Davenport, Iowa. Sire, Judge Blair 4667; dam, by Forward 1961. Height 15:3½ hands; weight 1210 pounds. Purchased February 1905.

1906—March 5, ch. f. Annette, foal No. 9, by Carmon 32917.

1907—September 9, br. c. Bonnie Boy, foal No. 22, by Carmon

32917. (Sold November 20, 1909, to I. J. King, Fort Collins, Colorado).
1908—Bred to Carmon 32917. (Not in foal).
1909—April 21, gr. s. Davenport, foal No. 52, by Carmon 32917.

Stud No. 7. Dakota, br. m.

Donated by Col. Gustav Pabst, Milwaukee, Wis. Height 15 hands; weight 1075 pounds.
1906—May 10, b. c. Archie, foal No. 10, by Carmon 32917. (Sold November 20, 1909, to M. J. Fitzpatrick, Fort Collins, Colorado).
1907—April 19, b. c. Balfour, foal No. 23, by Carmon 32917. (Placed in the stud in 1909).
1908—May 5, b. c. Carlyle, foal No. 37, by Carmon 32917. (Sold November 20, 1909, to John Mumm, Wellington, Colorado).
1909—April 6, b. c. died at birth.

Stud No. 8. Wisconsin, b. m.

Bred by August Uehlein, Milwaukee, Wis., foaled July 15, 1901. Height 15:1 hands; weight 1200 pounds; sire, Messenger Wilkes 3743; dam, Phallas Chief. Mare by King Piedmont 10983. Purchased February 1905. Removed from the stud 1909, to be destroyed.
1906—March 15, b. c. Avon, foal No. 11, by Carmon 32917. This foal was turned over to the College Farm on January 16, 1909, to be used for work purposes. This transfer was made in accordance with instructions from the Board of Survey dated August 4, 1906. This animal was blemished and was of no value for breeding purposes.
1907—September 5, b. c. Badger Boy, foal No. 24, by Carmon 32917. This foal was destroyed November 27, 1908, by order of the United States Department of Agriculture and the State Board of Agriculture, on account of unsoundness.
1908—July 22, b. f. Columbia, foal No. 38, by Carmon 32917.
1909—Not in foal.

Stud No. 9. Indiana br. m.

Bred by Rodewald Brothers, Rushville, Illinois. Height 15:1½ hands; weight 1080 pounds. Purchased February 1905.
1906—March 26, b. f. Alpha, foal No. 12, by Carmon 32917.
1907—April 1, br. f. Bonita, foal No. 25, by Carmon 32917.
1908—March 15, br. f. Clara, foal No. 39, by Carmon 32917.
1909—March 24, br. c. died March 24, 1909.

Stud No. 10. Georgia, b. m.

Bred by Walnut Park Farm, St. Joseph, Mo.,foaled 1900. Height 15:1½ hands; weight 1000 pounds; sire, Norcatur 17854; dam, Miami by Bay Star 11267. Purchased February 1905.
1906—April f. aborted.
1907—July 14, b. c. Ben Hur, foal No. 26, by Carmon 32917. (Sold to College Farm November 20, 1909, as a gelding).
1908—June 17, b. c. Colman, foal No. 40, by Carmon 32917. (Sold to College Farm November 20, 1909, as a gelding).
1909—May 28, b. f. Dolly Wilkes, foal No. 53, by Carmon 32917.

Stud No. 11. California, br. m.

Height 15:3½ hands; weight 1140 pounds. Purchased February 1905. (This mare was sold January 16, 1909, to Mr. Ward Tucker, Fort Collins, Colorado).
1906—April 7, br. c. Appollo, foal No. 13, by Carmon 32917. (This foal was sold January 16, 1909, to Mr. L. Kern, Fort Collins, Colorado).
1907—June 21, br. f. Beryl, foal No. 27, by Carmon 32917. (Destroyed January 5, 1908. Unsound).

1908—June 9, b. f. Cora, foal No. 41, by Carmon 32917.

Stud No. 12. Florida, b. m.

Height 16 hands; weight 1225 pounds. Purchased February 1905. (Sold January 16, 1909, to Mr. Ward Tucker, Fort Collins, Colorado).
1906—May 28, b. f. by Carmon 32917. (Died at birth).
1907—May 24, b. c. Bijou, foal No. 28, by Carmon 32917. (Died May 11, 1908; blood clot in heart).
1908—May 29, b. c. Curtiss, foal No. 42, by Carmon 32917. (Sold January 16, 1909, to S. H. Pierson, Denver, Colorado).

Stud No. 13. Minnesota, ch. m.

Bred by James Gibbons of Ohio; foaled 1895; height 16:1½ hands; weight 1415 pounds; sire, Harrison Chief 1606 (S); dam, by Britton. Purchased February, 1905. (Sold January 16, 1909, to Ivan Fisher, Fort Collins, Colorado).
1906—February 27, aborted twins, by Carmon 32917.
1907—May 11, ch. f. Boralma, foal No. 29, by Carmon 32917. (Sold January 16, 1909, to Smith Karnes, Fort Collins, Colorado).
1908—May 23, ch. f. Carrie, foal No. 43, by Carmon 32917. (Sold January 16, 1909, to G. W. Boston, Fort Collins, Colorado).

Stud No. 14. Illinois, bl. m.

Donated by Mr. W. C. Brown of New York, through Mr. E. H. Grubb, of Carbondale, Colorado. Height 15:3¾ hands; weight 1150 pounds. (This mare did not prove to be a satisfactory breeder and was recommended by the Board of Survey to be returned to Mr. E. H. Grubb).
1906—April 20, br. c. Arden, foal No. 14, by Carmon 32917. (Sold January 16, 1909, to Mr. C. Zimmerman, Fort Collins, Colo.).
1907—October 25, b. c. Brownie, foal No. 30, by Carmon 32917. (Sold January 16, 1909, to Mr. Alex Nelson, Fort Collins, Colo.).
1908—Not bred in 1907.
1909—May 8, ch. f. Dorata, foal No. 65, by Alva, stud No. 39.

Stud No. 15. Colorado, b. m.

Bred by Geo. D. Rainsford, Diamond, Wyoming, foaled 1896. Height 15:3½ hands; weight 1110 pounds; sire, Emigrant; dam, Hebe. a fine carriage horse untraced. Purchased December 28, 1904.
1905—June 24, b. c. Colorito, foal No. 1, by Indus 2131 (French Coach). This foal was turned over to the College Farm August 1908, to be used for work purposes.
1906—June 14, b. f. Amber, foal No. 15, by Carmon 32917.
1907—June 9, b. f. Bernice, foal No. 31, by Carmon 32917.
1908—Aborted November 1907, by Carmon 32917.
1909—April 12, b. c. Donald, foal No. 54, by Carmon 32917.

Stud No. 16. Montana, b. m.

Bred by Geo. D. Rainsford, Diamond, Wyoming. Foaled 1899; height 15:3½ hands; weight 1150 pounds; sire, Chappy, by Emigrant; dam, John Hughes' mare. Purchased December 28, 1904.
1905—May 23, b. f. Monella, foal No. 2, by Indus 2131 (French Coach). (This foal was sold January 16,1909, to Mr. L. Kern, New Windsor, Colorado).
1906—Bred to Carmon 32917. (Missed).
1907—May 5, b. c. Bonanza, foal No. 32, by Carmon 32917. (Destroyed May 1, 1908. Unsound).
1908—May 13, b. c. Carnagie, foal No. 44, by Carmon 32917.
1909—May 1, b. c. Dandy Jim, foal No. 55, by Carmon 32917.

Stud No. 17. Arizona, b. m.

Bred by Geo. D. Rainsford, Diamond, Wyoming. Foaled 1899; height 15:3½ hands; weight 1065 pounds; sire, Emigrant; dam, Hoyden, by Red Bud (Th). Purchased December 28, 1904.
1906—April 9, b. s. Albion, foal No. 16, by Carmon 32917.
1907—Bred to Carmon 32917. (Missed).
1908—Bred to Carmon 32917. (Missed).
1909—May 1, b. c. died at birth.

Stud No. 18. Wyoming, b. m.

Bred by Geo. D. Rainsford, Diamond, Wyoming. Foaled 1896; height 15:3¾ hands; weight 1180 pounds; sire, Red Bud (Th); dam, Lady Shepherd, by Spartan, Jr. Purchased December 28, 1904.
1905—June 18, b. c. Monte, foal No. 3, by Indus 2131 (French Coach). Donated to the College Farm August 1908 for work purposes.
1906—May 28, b. f. Alba, foal No. 17, by Carmon 32917.
1907—May 12, b. f. Bamba, foal No. 33, by Carmon 32917.
1908—April 25, b. f. Cinderella, foal No. 45, by Carmon 32917.
1909—Not in foal.

Stud No. 19. Nevada, b. m.

Bred by Geo. D. Rainsford, Diamond, Wyoming. Foaled 1899; height 15:2 hands; weight 1085 pounds; sire, Emigrant; dam, Gila, by Red Bud (Th). Purchased December 28, 1904.
1905—May 30, b. c. died of strangulation June 21, 1907.
1906—Bred to Carmon 32917. (Missed).
1907—Bred to Carmon 32917. (Missed).
1908—Bred to Carmon 32917. (Missed).
1909—Not in foal.

Stud No. 20. Idaho, br. m.

Bred by Geo. D. Rainsford, Diamond, Wyoming. Foaled 1899; height 15:3 hands; weight 1240 pounds; sire, Chugladdie, by Spartan, Jr.; dam, Hill Bud, by Red Bud (Th.) Purchased December 28, 1904.
1905—May 7, br. m. Idalia, foal No. 4, by Indus 2131 (French Coach). (Sold January 16, 1909, to S. G. Pierson, Denver, Colorado).
1906—July 9, br. m. Amelia, foal No. 18, by Carmon 32917. (Sold August 27, 1909, to C. Zimmerman, Fort Collins, Colorado).
1907—Bred to Carmon 32917. (Missed).
1908—Bred to Carmon 32917. (Missed).
1909—May 4, b. f. Dorothy, foal No. 56, by Carmon 32917.

Stud No. 21. Idalia, br. m.

Bred by Geo. D. Rainsford, Diamond, Wyoming, Foaled May 7, 1905; height 15:3 hands; weight 1275 pounds; sire, Indus 2131 (French Coach); dam, Idaho, by Chugladdie. Purchased in Utero. (Sold January 16, 1909, to S. G. Pierson of Denver, Colorado).
1907—Bred to Carmon 32917. (Missed).

Stud No. 22. Monella, b. m.

Bred by Mr. Geo. D. Rainsford, Diamond, Wyoming. Foaled May 23, 1905; height 15:3 hands; weight 1180 pounds; sire, Indus 2131 (French Coach); dam, Montana, by Chappy. Purchased in Utero. (Sold January 16, 1909, to Mr. L. Kern, New Windsor, Colorado).
1908—May 19, b. c. Colonel, foal No. 46, by Carmon 32917. (Sold January 16, 1909, to S. G. Pierson, Denver, Colorado).

Stud No. 23. Beatrice, b. m. 2079 (S).

Bred by Gay Brothers, Pisgah, Kentucky. Foaled 1901; height 15:3 hands; weight 1200 pounds; sire, Highland Denmark 730 (S); dam, Lady Adams 2074 (S), by Harrison Chief (S). Purchased June, 1906.

1907—September 14, b. f. Belladonna, foal No. 34, by Carmon 32917.

1908—Bred to Carmon 32917. (Missed).

1909—March 3, b. f. Daisy Deane, foal No. 27, by Carmon 32917.

Stud No. 24. Mambrina, ch. m. 2400 (S).

Bred by Village Farm, East Aurora, Kentucky. Foaled April 6, 1903; height 15:2 hands; weight 1050 pounds; sire, King Lancelot 32855, by Mambrino King 1279; dam, Snowdrop 2398 (S), by Mambrino King 1279. Purchased June 1906.

1907—Bred by Carmon 32917. (Missed).

1908—April 27, ch. c. Castleman, foal No. 47, by Carmon 32917. (Sold November 20, 1909, to Geo. L. Gross, Fort Collins, Colorado, as a gelding).

1909—Not in foal.

Stud No. 25. Mira, ch. m.

Donated by ex-Governor Adams of Pueblo, Colorado; height 16 hands; weight 1200 pounds; bred by S. Lehman, Newton, Kansas. Sire, Dameon 19936; dam, by Black Hawk McGregor, by Robert McGregor 647. Donated March 1907.

1908—July 7, b. f. by Carmon 32917. (This foal was transferred to Hon. W. J. Bryan, Lincoln, Nebraska, November 4, 1909, by order of Hon. Alva Adams, who was to receive the colt in lieu of donation of mare).

1909—Not in foal.

Stud No. 26. Gaiety Girl, br. m.

Bred by Geo. D. Rainsford, Diamond, Wyoming. Foaled 1895; height 15:3 hands; weight 1175 pounds. Purchased August 8, 1907.

1908—April 30, bl. m. Carnation, foal No. 48, by Emigrant.

Stud No. 27. Golden Picture, ch. m. 2788 (S).

Bred by J. Gano Johnson, Mount Sterling, Kentucky. Foaled 1903; height 15:3½ hands; weight 1150 pounds; sire, Wilson's King 2196 (S); dam, Lady Bourbon 2782 (S), by Bourbon Chief 976 (S). Purchased March 1908.

1908—April 19, ch. c. Congressman, foal No. 49, by Golden King 2359 (S). (To be sold).

1909—May 16, ch. f. by Golden King 2359 (S). Died at birth.

Stud No. 28. Bethel Princess, ch. m. 4796 (S).

Bred by Mose Hendricks, Bath County, Kentucky. Foaled 1902; height 15:2 hands; weight 1125 pounds; sire, Wilson's King 2196 (S); dam, by Sim Clark's Chief 2575 (S). Purchased March 1908.

1908—April 22, ch. f. Columbine, foal No. 50, by Cloud King 2198 (S).

1909—May 26, ch. c. Diamond King, foal No. 59, by Golden King 2359 (S).

Stud No. 29. Barthenia McCord, b. m. 3223 (S).

Purchased from A. G. Jones, North Middletown, Kentucky. Foaled 1894; height 15:3 hands; weight 1200 pounds; sire, Chester Dare 10 (S); dam, by Peavine 85 (S). Purchased March 1908.

1908—May 5, b. m. c. Chester Bourbon, foal No. 51, by Bourbon King 1788 (S).

1909—May 22, b. f. Della McCord, foal No. 60, by Bourbon King 1788 (S).

Stud No. 30. Elvira Lindsey, b. m. 3083 (S).

Bred by J. H. Lindsey, Flemnig County, Kentucky. Foaled 1900; height 15 hands; weight 1050 pounds; sire, Wilson's King 2196 (S); dam, by Red Cloud (Wyatts) 2197 (S). Purchased March 1908.

1908—May 15, b. m. by Bourbon King 1788 (S). Died June 22 1908, of distemper.

1909—June 1, ch. f. Dora Cloud, foal No. 61, by Bourbon King 1788 (S).

Stud No. 31. Arba, b. m.

Bred by Colorado Experiment Station, Fort Collins, Colorado. Foaled April 4, 1906; height 15:3½ hands; weight 1225 pounds; sire Carmon 32917; dam, Virginia.

1909—June 10, b. c. Denver, foal No. 62, by Carmon 32917.

Stud No. 32. Anita, b. m.

Bred by the Colorado Experiment Station, Fort Collins, Colorado Foaled February 27, 1906; height 15:2½ hands; weight 1150 pounds; sire, Carmon 32917; dam, Kentucky, by Harrison Chief 1606 (S).

1908—Bred to Carmon.

1909—April 15, ch. c. by Carmon 32917. (Stillborn).

Stud No. 33. Annette, ch. m.

Bred by the Colorado Experiment Station, Fort Collins, Colorado Foaled March 5, 1906; height 15:3 hands; weight 1175 pounds sire, Carmon 32917; dam, Iowa, by Judge Blair 4667.

1908—Bred to Carmon 32917.

1909—May 28, ch, c. by Carmon 32917. (Died at birth).

Stud No. 34. Alpha, b. m.

Bred by the Colorado Experiment Station, Fort Collins, Colorado Foaled March 28, 1906; height 15:3 hands; weight 1150 pounds sire, Carmon 32917; dam, Indiana.

1908—Bred to Carmon.

1909—May 31, b. c. Defiance, foal No. 63, by Carmon 32917. (Destroyed August 25, 1909, on account of fractured leg.

Stud No. 35. Ada, b. m.

Bred by the Colorado Experiment Station, Fort Collins, Colorado Foaled March 21, 1906; height 15:2 hands; weight 1100 pounds sire, Carmon 32917; dam, Michigan, by Prince L 5947.

1909—May 12, b. c. Defender, foal No. 64, by Albion Stud No. 37.

Stud No. 36. Alba, b. m.

Bred by the Colorado Experiment Station, Fort Collins, Colorado Foaled May 28, 1906; height 16 hands; weight 1175 pounds sire, Carmon 32917; dam, Wyoming, by Red Bud (Th).

1909—Not in foal.

Stud No. 37. Albion, b. s.

Bred by the Colorado Experiment Station, Fort Collins, Colorado Foaled April 9, 1906; height 16:1 hands; weight 1275 pounds sire, Carmon 32917; dam, Arizona, by Emigrant.

Used in stud in 1908.

The following table shows the service record of Albion for the years of 1908-1909:

SERVICE RECORD OF ALBION, 1908-1909.

Year	Station Mares		Outside Mares		Total No. Mares Served Once	Total No. Returned	Total No. Mares Bred	Foals Got	Per cent age Foals Got
	Bred	Foals	Bred	Foals					
1908	2	1	2	2	1	3	4	3	75 00
1909	2	.....	4	.....	3	3	6	.....	.....

SUMMARY OF ANIMALS IN STUD AT PRESENT.

Total number of stallions in service..... 4
Total number of mares in service..... 29
Total number of foals in stud not in service..... 27
Total number of animals in stud..... 60

The above summary is complete and upon close study will show that the record of the majority of the animals connected with the station has been very satisfactory. The work has progressed very nicely, but the need for infusion of new blood with the Carmon offspring is apparent. This may result in the purchase of a new stallion for next season, or the shipment of mares to outside points for breeding. Our experience with inbreeding during the past season does not fully justify the pursuance of this course to a very extended degree at this time. Inbreeding will need be done at some future time to ultimately fix the type, but at the present it is not advisable to pursue this course.

The experiment at present contains sixty animals of superior merit. The surplus animals of inferior qualities have been eliminated. The maturing foals included with those remaining in the station are very promising animals, and a majority of them should develop into very worthy specimens. The policy of close selection of the best individuals having been inaugurated should be continued each succeeding year. No breed or type has ever been established without the strictest observance of this policy. The results already attained are indeed very encouraging, and with the same degree of progress manifested in the future, the outcome is assured.

Respectfully submitted,

J. O. WILLIAMS,
Expert-in-Charge.

REPORT OF THE AGRONOMIST.

To the Director:

I submit herewith the report of work in the plant industry section.

Owing to the lateness of my arrival, no new work was taken up in the spring of 1909. An effort was made to continue through the season, lines of work begun by my predecessors.

New lines of work planned include investigations of methods of breeding cereal crops, breeding or obtaining adapted feed grains, early maturing wheats, spring and winter grains for high altitudes, improvement of the field pea and methods for its best production, Colorado rotations, Colorado farm management and causes for the deterioration in quality of spring milling wheat, if the local opinion that deterioration occurs can be established.

During the summer some time was spent in getting acquainted with special conditions of Colorado crops, soils, and climate, with their altitude and topographic relations.

It is necessary to do this in order to become acquainted with the special needs of the state, the information being necessary for the preparation of intelligent new plans.

The work of the department could be greatly strengthened by the addition of field men. A field man is needed at the present time in the San Luis Valley to study problems of pea production and improvement, wheat problems, oat problems, and barley problems. These are most urgent, but the pasture question and root crops will soon need attention; as more dairying is sure to be carried on as settlement increases. Farmers, new settlers, in the new districts need help on these raw lands and a field man for this purpose would be of great help.

Plans are being devised for the improvement and distribution of new and adapted seeds for various regions of the state. While all of such work is not experimental, it is within the proper province of the station, where proper funds are used.

Respectfully submitted,

ALVIN KEYSER,
Agronomist.

REPORT OF THE ANIMAL HUSBANDMAN.

To the Director:

Dear Sir: I hereby submit a report upon animal investigations for the past year.

The results of all unpublished experimental work done prior to November, 1908 have been prepared and offered for publication. These are as follows:

Experiments with Steers, W. L. Carlyle and G. E. Morton, (published as bulletin 149).

Experiments with Lambs, 1906-1907, 1907-1908. W. L. Carlyle and G. E. Morton. (In press.)

The results of experiments conducted during the year 1908-1909 are being held for publication in connection with further work to be done during 1909-1910. These completed, unpublished experiments are as follows:

EXPERIMENTS WITH LAMBS.

Lot 1. Alfalfa hay, whole; barley.
Lot 2. Alfalfa hay, whole; corn.
Lot 3. Alfalfa hay, chopped; corn.

The results of these experiments are not what were expected because of dogs getting into the corrals and worrying the sheep. The loss from such a cause will be of interest in itself to lamb feeders, and will be the chief item for publication as the result of the experiments.

EXPERIMENTS WITH SWINE.

Trials of Tankage.

Lot 1. Corn, 3 parts; barley, 3 parts; selected tankage, 1 part.
Lot 2. Corn, 6 parts; fertilizer tankage, 1 part.
Lot 3. Corn, 6 parts; selected tankage, 1 part.
Lot 4. Corn 3 parts; selected tankage, 1 part.
Lot 5. Corn, 3 to 5 parts; selected tankage, 1 part.
Lot 6. Corn, 2 parts; wheat shorts, 1 part.

EXPERIMENTS WITH SWINE.

Trials of Brewers' Grains.

Lot 7. Corn, 2 parts; wheat shorts, 1 part.
Lot 8. Corn, 2 to 4 parts; brewers' grains, 1 part.
Lot 9. Corn 4 to 6 parts; brewers' grains, 1 part.
Lot 10. Corn, 2 to 4 parts; brewers' grains, 1 part.

The results with selected tankage were favorable, with fertilizer tankage fairly favorable, and with brewers' grains unfavorable.

Respectfully submitted,

G. E. MORTON,
Animal Husbandman.

REPORT OF FARM MACHINERY & DAIRYING.

To the Director:

Dear Sir: I hereby respectfully submit the following annual report of experimental work in farm mechanics and dairying.

In the last annual report we stated that the work on the "Cement and Concrete Fence Posts" was completed by November 1, and that we hoped to publish the results by November 30, 1908. Considerable more work was done on this investigation during the early part of this year, by both myself and my assistant. The data for the bulletin on this subject was presented for publication on June 26, of this year and was printed at once.

Two other outlines for investigational work were presented in the last annual report on the subjects of: Feed Grinders, Cutters and Crushers. Farm Buildings and Constructions. Nothing has been done on either of these.

Considerable time has been spent by myself since September 1, making investigations as to the present condition of the dairy industry in Colorado. On September 13 an outline was presented and accepted on the subject of "Dairying in Colorado." The objects of an investigation of this kind being to help improve the various dairy conditions of the state, taking up the work from the standpoint of milk production, its care, handling it for farm butter, city milk supply, creameries and cheese factories. To show the importance of the Babcock tester, scales, hand separator and improved methods of handling dairy produces, etc. This information to be obtained by visiting various dairies and creameries throughout the state, securing data, photographs, plans, etc. To use such material as has already been collected by correspondence, visits, otherwise. To make more extensive inquiry by correspondence. Fifteen hundred circular letters of questions have just been published and are partly distributed among the dairy porducers of the state. All of these will be mailed during the next few days. We hope to have this data ready for publication by January, 1, 1910.

On October 1, 1909, an outline was presented for investigational work on "The Life of Farm Machinery." The object being to determine what the actual life of farm machinery is, under favorable and unfavorable conditions. To suggest methods of better care and handling.

This data and illustrations to be collected by making visits to various farms in the state. The larger part of it must be collected by correspondence. We hope to have this data ready for

publication by September 1, 1910.

A large number of inquiries have been answered by correspondence during the past year along farm machinery, concrete and dairy lines.

Considerable time has also been given to making field trials of various farm implements, the results of which have been reported only in a general way.

Respectfully submitted,

H. M. BAINER,

Farm Machinery and Dairying.

REPORT OF THE ARKANSAS VALLEY FIELD AGENT.

To the Director:

I herewith submit a general report of the field work at Rocky Ford.

During my absence, while filling the position of Agronomist at the college, some of the plans outlined, were somewhat interrupted, but by making several trips to Rocky Ford, the general outline for the alfalfa seed breeding was carried out.

Five acres were sown to alfalfa in rows, twenty inches apart, with seed collected from the alfalfa nursery, from the most highly promising plats; this field has made a splendid development, and it will be more valuable the coming year, to test the merits of the selections, and also to try the row system, as a method for seed production, for growing sufficient quantity of seed, to make comparative tests in different sections of the state.

The seed of a few individual selections, together with some new alfalfa from Europe, furnished by Mr. J. M. Westgate, were also planted, and have become well established as an addition to the alfalfa nursery.

Observations and selections for frost resistance, and other desirable traits and efficient qualities were carefully made with a view to establish a larger and more practical alfalfa nursery, of types showing strong points for utility, seed from over one hundred choice individual plants were collected for this purpose, also several lots of seed from some exceptionally good plats that can be used to sow additional increase plots.

The most important question in the alfalfa investigation seems to be the establishing of some fixed varieties of alfalfa, with inherent traits, to reproduce the desired qualities uniformly, and to ascertain the combinations of qualities best suited to the varied sections of the state, also to determine the best method of producing seed in sufficient quantity to make comparative tests in each different section, and eventually making the results available to the farmers.

The situation of the "rust" resisting cantaloupe investigation seems to be about exhausted for the present, at least, the ultimate results are to the effect, that growers in general recognize the value of the disease resistant feature of the Pollock cantaloupe, and it is quite generally planted, thus accomplishing a great improvement in the quality of the late cantaloupes, the early strain that is not disease resistant deteriorates rapidly about the middle of the sea-

son, while the "rust" resistant cantaloupe natures good fruit until frost, this strain has also become very popular in the eastern and southern states, where it is practically the only variety that can be successfully grown with excessive rains.

Seed of the "rust" resistant cantaloupe have been furnished to all growers upon request within the state and also to many growers and experiment stations of other states, this strain is now being grown especially for seed, by the Rocky Ford Cantaloupe Seed Breeders' Association, an organization of a few growers, that are employing the same system of seed selection that was developed by the investigation.

The only serious drawback to the strain is its late maturity. To remedy this defect many selections and several hybrids have been made during the past three years, one selection of these promise the desired combination of early maturity and disease resistance. This selection has passed two seasons' test with remarkable results. A report of this selection, and some other unpublished material with a general resume on the subject of Cantaloupe Culture, might make a desirable bulletin, and a fitting close to the past cantaloupe investigations.

Several weeks were occupied in attempts to combat the melon aphis with fumigation, with rather indifferent results, a report of which has been outlined to Professor Gillette.

During the winter months lectures were given in the farmers' short courses at Maple Grove, Colbran, New Castle, Hotchkiss, Delta, Montrose, Rocky Ford, Trinidad, Fort Morgan and Fort Lupton, and assistance was given at several summer institutes.

Respectfully submitted,

Rocky Ford, Colorado,
December 1, 1909.

PHILO K. BLINN,
Field Agent.

REPORT OF THE PLAINS SUBSTATION.

To the Director:

On November 5th, 1908, there was sown fifteen acres of Turkey Red wheat. Owing to the extremely heavy winds during the spring of 1909, there were five acres blown out, and the balance of ten acres was cut and threshed and yielded fifteen and one-half bushels to the acre, of good quality, which brought ninety cents per bushel at the elevator at Cheyenne Wells, the day it was threshed. The five acres which were blown out was sown to millet and yielded about two tons per acre.

About the 9th day of May, 1909, I planted eight acres to White Australian and common field corn, which yielded about thirty bushels per acre.

About May 13th, 1909, I planted five acres to dwarf kafir corn, which yielded twenty bushels to the acre.

On or about the 26th day of April, 1909, I sowed ten acres to Red Texas oats, which was blown out quite badly, resulting in a very light crop which was cut for hay.

The trees were badly affected with the drought and the late freezes during the spring of 1908, so that the small fruit was almost an entire failure. There were about five bushels of apples, but owing to the heavy hail which we experienced in the latter part of June they were badly scarred and one sided making it a very imperfect crop. No peaches matured.

Because of the excessive rains which fell during the balance of the summer, the trees have all made a very rich growth and prospects are good for the coming season.

Respectfully submitted,

Cheyenne Wells, Colorado,
December 1, 1909.

J. B. ROBERTSON,
In Charge.

THIRTY-SECOND ANNUAL REPORT

OF

The State Board of Agriculture

OF COLORADO

INCLUDING THE TWENTY-THIRD ANNUAL REPORT

OF THE

Colorado Agricultural Experiment Station

THE STATE AGRICULTURAL COLLEGE

Fort Collins, Colorado

1910

THE STATE BOARD OF AGRICULTURE

LETTER OF TRANSMITTAL.

Fort Collins, Colo., Nov. 15, 1910.

Sir—I have the honor to submit to you the annual report of The State Board of Agriculture, for the year 1910, containing an inventory of the property under the direction of the Board, with the exception of the land grant made to the State by the United States as an endowment for the Agricultural College when the Morrill Act was accepted by the Legislature and the Agricultural College established; the financial report of the Secretary, showing the receipts and disbursements for the fiscal year ending November 30, 1910; the report of the President of the College, covering the work of instruction, experimentation and research, and extension carried on under the direction of the Board during the year.

Respectfully submitted,

A. A. EDWARDS,

President, The State Board of Agriculture of Colorado.

To His Excellency

John F. Shafroth,

Governor of Colorado:

THE STATE AGRICULTURAL COLLEGE.

Fort Collins, Colorado, November 30, 1910

Sir:

I submit herewith my report for the year 1910, accompanied by the reports of the Director of the Agricultural Experiment Station, the Superintendent of Extension, the Principal of the School of Agriculture, and the Farm Manager, all of which are submitted as a part of my report of the year's work of the State Agricultural College.

Respectfully submitted,

CHAS. A. LORY,

President, State Agricultural College.

To the President,

State Board of Agriculture:

THE STATE BOARD OF AGRICULTURE.

HON. B. F. ROCKAFELLOW.....Canon City, 1911.
HON. EUGENE H. GRUBB.....Carbondale, 1911.
HON. A. A. EDWARDS.....Fort Collins, 1913.
DR. R. W. CORWIN.....Pueblo, 1913.
HON. FRANKLIN E. BROOKS.....Colorado Springs, 1915.
HON. JARED L. BRUSH.....Greeley, 1915.
HON. E. M. AMMONS.....Littleton, 1917.
HON. JOHN C. BELL.....Montrose, 1917.
GOVERNOR JOHN F. SHAFROTH, } Ex-officio.
PRESIDENT CHAS. A. LORY, }

OFFICERS.

HON. A. A. EDWARDS.....President
HON. JARED L. BRUSH.....Vice-President
L. M. TAYLOR.....Secretary
GEO. A. WEBB.....Treasurer

STANDING COMMITTEES.

Executive

A. A. EDWARDS — J. L. BRUSH — E. M. AMMONS

Finance

F. E. BROOKS — R. W. CORWIN — J. L. BRUSH

Farm, Stock and Veterinary Science

E. H. GRUBB — J. L. BRUSH — JOHN C. BELL

Faculty and Courses of Study

E. M. AMMONS — F. E. BROOKS — JOHN C. BELL

Botany, Horticulture and Entomology

R. W. CORWIN — E. M. AMMONS — E. H. GRUBB

Mathematics, Engineering and Military Science

B. F. ROCKAFELLOW — E. H. GRUBB — E. M. AMMONS

Mechanics, Chemistry and Electrical Engineering

F. E. BROOKS — JOHN C. BELL — R. W. CORWIN

College Lands and Leases

JOHN C. BELL — J. L. BRUSH — B. F. ROCKAFELLOW

College Buildings and Permanent Improvements

J. L. BRUSH — E. M. AMMONS — R. W. CORWIN

Home Economics, Library and Music

R. W. CORWIN — E. H. GRUBB — B. F. ROCKAFELLOW

History, Literature, English and Rhetoric

C. A. LORY — B. F. ROCKAFELLOW — J. L. BRUSH

Farmers' Institutes

E. M. AMMONS — JOHN C. BELL — F. E. BROOKS

Salaries

E. M. AMMONS — F. E. BROOKS — B. F. ROCKAFELLOW

INVENTORY OF LANDS.

College Farm, 320 Acres	$128,000
East Farm, 152 Acres	76,000
Pasture, 1,350 Acres	21,000
Cheyenne Wells, 160 Acres	4,000
Total	$229,000

INVENTORY OF BUILDINGS.

Conservatory of Music	$ 4,650.00
Electrical Building	9,000.00
Main Building	58,000.00
Chemical Laboratory	30,000.00
Hose House	75.00
Depot	200.00
Lavatory	3,500.00
Horticultural Building	15,000.00
Greenhouses	4,200.00
Potting House	300.00
Library	5,000.00
Zoology	8,000.00
Mechanical Engineering	30,000.00
Mechanical Engineering Laboratory	2,000.00
Simon Guggenheim Hall	53,000.00
Pathology Laboratory	2,300.00
Veterinary Hospital	1,200.00
Anatomy Laboratory	100.00
Anatomy Building	700.00
Bunk House	150.00
Coal House	150.00
Small Animal Ward	100.00
Box Stalls	150.00
Civil and Irrigation Engineering	75,000.00
Poultry Plant Residence	1,000.00
Workshop	85.00
Main Chicken House	450.00
Ten Colony Coops	500.00
Agricultural Hall	10,500.00
Andrews Group:	
"Andrews" House	10,000.00
Chicken House	25.00
Bunk House	100.00
Ice House	100.00
Experiment Station Horse Paddock Shed	100.00
Experiment Station Horse Paddock Shed (2)	200.00
Experiment Station Horse Barn	5,000.00
Experiment Station Horse Barn, Stone	1,000.00

Agronomy Seed House	3,200.00
Miller Group:	
Dwelling (East)	1,200.00
Ice House	200.00
Chicken House	25.00
Brick Hay Storage Building	600.00
Cellar	250.00
Wood Shed	20.00
Dwelling (West)	500.00
Cellar	75.00
Wagon Shed	25.00
Barn	250.00
Hill Pasture Shed	300.00
Hill Pasture Bunk House	25.00
Farm Division:	
Farm Superintendent's Residence	3,500.00
Farm Superintendent's Barn	200.00
Chicken House	125.00
Implement Shed and Granary	6,150.00
Work Shop	600.00
Bunk House	200.00
Barn (Horse)	5,000.00
Barn (Dairy)	4,000.00
Experiment Hog Feeding Shed	500.00
Piggery	1,000.00
Bull Shed	200.00
Stallion Shed	200.00
Steer Barn	1,500.00
Colt Shed	100.00
Dairy Shed	500.00
Experiment Grain Shed (Steers)	100.00
Experiment Steer Shed	400.00
Sheep Barn	500.00
Experiment Grain Shed (Sheep)	20.00
Buck Shed	20.00
Lambing Shed	15.00
Concrete Potato Cellar	1,200.00
Stock Judging Pavilion	4,500.00
Total	$368,900

INVENTORY OF EQUIPMENT BY DEPARTMENTS

Agronomy	$ 146.75
Animal Husbandry	12,785.45
Botany and Forestry	1,463.64
Chemistry	5,000.00
Civil and Irrigation Engineering	11,506.00
Farm	11,703.00

Farm Mechanics	9,457.25
Farmers' Institutes	573.35
Home Economics	2,204.78
Horticulture	2,269.50
Library	49,804.09
Mathematics	522.00
Mechanical Engineering	21,192.15
Military Science	131.40
Modern Language	400.00
Physics and Electrical Engineering	9,504.86
President's Office	539.00
Registrar's Office	555.43
Rhetoric and Composition	780.50
School of Agriculture	186.00
Secretary's Office	1,035.00
Veterinary Science	5,289.72
Zoology and Entomology	11,843.85
Total	$159,793.72

AGRICULTURAL EXPERIMENT STATION, INVENTORY OF EQUIPMENT.

Animal Investigation	$ 2,354.00
Arkansas Valley Field Station	4,528.75
Bacteriological Investigation	2,045.59
Botanical Section	1,715.00
Chemical Section	2,469.07
Cheyenne County Experiment	3,885.20
Director's Office	6,346.72
Entomological Section	1,564.12
Fruit Investigation	260.75
Horse Investigation	11,691.15
Horticultural Section	494.15
Irrigation Engineering Section	7,028.64
Plant Industry	2,946.15
Potato Investigation	1,831.43
Veterinary Section	688.75
Total	**$49,849.47**

SUMMARY.

Value of Lands, Not Including Congressional Grant	$ 229,000
Value of Buildings	368,900
Equipment	209,643
Total	807,543

SECRETARY'S CASH ACCOUNT.

December 1, 1908 to and Including November 30th, 1909

Receipts.

Animal Husbandry	$ 3,344.54
Farm Department	1,721.73
Farmers' Institutes	3,151.55
General Agriculture	107.75
Farm Mechanics	103.08
Botany and Horticulture	166.00
Chemical Department	155.33
Civil and Irrigation Engineering	312.40
Library	12.52
Library Fee	375.00
Mechanical Engineering	46.95
Music Department	40.00
Physics and Electrical Engineering	42.70
Veterinary Science	331.68
Girl's Dormitory	100.00
Permanent Improvements	1,200.72
Current Expense	91.80
General Repairs	1.39
Entrance Fees	189.00
Lights	4 00
Miscellaneous Sales	144.25
Transfers—College Funds	2,313.91
Transfers—Experiment Station Funds	4,049.59
Agronomy Division	152.89
Animal Investigation	2,678.23
Arkansas Valley Field Agent	874.50
Director and General	.75
Horticultural Section	203.09
Veterinary Section	330.07
Fruit Investigation	40.00
Plant Industry	9.01
Horse Investigation	4,221.25

Disbursements

College Special Fund—Paid College Treasurer		13,956.30
Experiment Station Special Fund—Paid Ex. Sta. Treas.		12,559.38
	$ 26,515.68	$26,515.68

DISBURSEMENTS—COLLEGE FUNDS

For the Year 1908-1909

Agronomy	883.67
Animal Husbandry	5,997.32
Farm Mechanics	574.23
Farm Department	6,790.21
Farmers' Institutes	7,825.63
General Agriculture	2,405 91
Bookkeeping	13.47
Botany and Horticulture	1,791.31
Chemical	648.67
Civil and Irrigation Engineering	240.88
Constitutional History and Irrigation Law	18.25
Domestic Science	561.47
History and Literature	104.72
Library	1,736.39
Mathematics	15.67
Mechanical Engineering	1,859.91
Military	201.05
Modern Languages	13.12
Music Department	430.42
Physical Training	148.16
Physics and Electrical Engineering	789.25
Salary	$ 75,733.34
President's Office	845.26
Secretary's Office	921.01
Rhetoric and Composition	130.49
Veterinary Science	3,653.58
Zoology and Entomology	88.63
State Board of Agriculture	1,464.66
Quarterly Bulletins and Reports	937.22
College Campus	1,414.17
Insurance	522.00
Student Labor	2,348.26
Firemen and Janitors	4,724.28
Fuel	3,171.11
Advertising	1,178.39
Permanent Improvements	3,819.74
Current Expense	2,031.47
General Repairs	1,365.35
Furniture and Fixtures	79.55
Irrigation Building	35,425.20
Lights	835.48
Water Assessments	1,183.48
Library Fee	449.80
Power	27.30

State Entomologist	144.95
Electrical Supplies	251.91
Registrar's Office	90.77
School of Agriculture	533.75
Land and Water	12,563.96
Total	$188 984.82

DISBURSEMENTS—EXPERIMENT STATION

For the Year 1908-1909

Salaries	$ 16,941.67
Agronomy Section	170.98
Animal Investigation	4,330.54
Arkansas Valley Field Agent	59.32
Bulletins and Reports	3,087.83
Chemical Section	958.40
Director and General	1,680.19
Entomological Section	825.87
Horticultural Section	1,042.99
Irrigation Section	1,753.75
Library	65.90
Veterinary	623.01
Fruit Investigation	5,287.25
Plant Industry	2,070.11
Horse Investigation	6,063.42
Farm Mechanics	547.80
Poultry Experiments	1,523.17
Potato Investigation	2,326.16
Secretary's Office	100.60
Bacteriological Section	188.00
Farm Machinery and Roads	283.99
Total	$ 49,930.95

RECEIPTS AND DISBURSEMENTS:

	Balance Dec. 1, 1908. State Treasurer	College Treasurer	Receipts	Transfers to	Transfers from	Disbursements.	Balance Nov. 30, 1909. State Treasurer	College. Treasurer
Agricultural College								
Tax Fund	$ 1,299.41	$25,554.66*	$73,324.73	.....	.....	$82,442.18	$27,375.86*	$ 5,996.84*
Land Income Fund	461.36	43.21	7,966.87	.....	.....	7,858.26	28.23	584.95
Special Fund	.....	101.32	11,642.39	2,313.91	.....	10,732.15	.....	3,325.47
†Secretary's Revolving Fund	.....	1,500.00	.....	.....	.....	.....	.....	1,500.00
Mechanic Arts Fund	.....	20,404.49	40,000.00	.....	.....	38,343.08	.....	22,061.41
Appropriation—Irrig. Bldg.	.....	.....	40,000.00	.....	.....	35,425.20	20,000.00	15,425.20*
Appropriation—F'rm's' Ins.	.....	.....	10,000.00	.....	2,313.91	1,619.99	5,000.00	1,066.10
Appropriation—Land-Wat'r	.....	.....	16,372.38	.....	.....	12,563.96	8,186.19	4,377.77*
Experiment Station								
Hatch Fund	.....	1,975.54	15,000.00	.....	.....	13,416.37	.....	3,559.17
Adams Fund	.....	1,399.84	12,000.00	.....	.....	10,906.00	.....	2,493.84
Special Fund	.....	10,895.02	8,509.79	4,049.59	.....	13,077.94	.....	10,376.46
Appropriation—Ani. Inv.	.....	.....	10,000.00	.....	355.59	2,808.04	5,000.00	1,836.37
Appropriation—Plant Ind.	.....	.....	8,000.00	.....	.....	1,410.39	4,000.00	2,589.61
Appropriation—F M & Rds.	.....	.....	5,000.00	.....	.....	283.99	2,500.00	2,216.01
Appropriation—Fruit Inv.	.....	.....	10,000.00	.....	1,962.22	2,025.14	5,000.00	1,012.64
Appropriation—Potato Inv.	.....	.....	10,000.00	.....	488.98	1,837.18	5,000.00	2,673.84
Appropriation—Polty. Exp.	.....	.....	5,000.00	.....	.....	1,523.17	2,500.00	976.83
Appropriation—Horse Inv.	.....	.....	5,000.00	.....	1,242.80	2,642.73	2,500.00	1,385.53*
Appropriation—Chey. C. Ex.	.....	.....	2,000.00	.....	.....	.....	1,000.00	1,000.00
Total	$1,760.77	$10,764.76	$289,816.16	$6,363.50	$6,363.50	$238,915.77	$33,338.56	$30,087.36

†In Secretary's Hands.
*Overdraft.

FINANCIAL STATEMENT.
THE STATE AGRICULTURAL COLLEGE,
Fort Collins, Colo.

SECRETARY'S CASH RECEIPTS.

Dec. 1, 1909, to and Including Nov. 30, 1910.

COLLEGE.

Animal Husbandry Department	$ 3,889.79
Building Superintendent	10.00
Chemical Department	141.66
Civil and Irrigation Engineering	126.71
Entrance Fees	2,540.00
Farm Mechanics	34.20
Farm Department	7,640.61
Horticultural Department	272.06
Library	3.47
Mechanical Engineering	20.05
Miscellaneous Collections	798.20
Physics and Electrical Engineering	26.05
Rents	397.00
State Entomologist	180.15
Veterinary Department	816.06
Total	$16,896.01

EXPERIMENT STATION.

Animal Investigation	$ 8,415.29
Farm Machinery and Roads	290.65
Horse Investigation	2,229.36
Horticultural Section	182.73
Irrigation Section	34.10
Plant Industry	137.65
Potato Investigation	365.09
Poultry Experiments	55.30
Total	$11,710.17

DISBURSEMENTS.

College Special Fund—Paid College Treasurer	$16,896.01	
Exp. Station Special Fund—Station Treasurer	11,710.17	
	$28,606.18	$28,606.18

DISBURSEMENTS ON EXPERIMENT STATION FUNDS

For the Year 1909-1910

Department or Section	Hatch	Adams	Special	Appropriation	Total
Salary	7,755.94	9,577.72	1,873.51	.....	19,207.17
Ark. Val. Field Agent	265.27	.....	.....	.....	265.27
Building	750.00	500.00	.....	.....	1,250.00
Bulletins and Reports	2,184.49	.....	1,440.53	.....	3,625.02
Chemical	152.45	2,048.25	.45	.....	2,201.15
Director and General	1,604.22	2.36	60.75	.....	1,667.33
Entomological	490.10	420.46	.....	.....	910.56
Horticultural	280.25	33.15	35.00	.....	348.40
Irrigation	1,846.61	742.67	.97	.....	2,590.25
Library	91.31	65.59	.....	.....	156.90
Veterinary Science	206.51	.....	496.23	.....	702.74
Fruit	.....	.....	46.10	6,012.64	6,058.74
Plant Industry	104.00	.....	155.97	6,589.61	6,849.58
Horse Investigation	.....	.....	2,318.55	1,114.47	3,433.02
Secretary's Office	244.21	26.47	30.15	.....	300.83
Bacteriological Inv'st'g'n	.....	1,050.81	.....	.....	1,050.81
Botany	.....	5.80	16.45	.....	22.25
Animal Investigation	.....	.....	8,462.66	6,836.37	15,299.03
Plains Investigation	.....	.....	52.97	.....	52.97
Potato Investigation	.....	.....	86.86	7,673.84	7,760.70
Poultry Investigation	.....	.....	65.71	3,476.83	3,542.54
Farm Machinery & Road	.....	.....	554.03	4,716.01	5,270.04
Cheyenne County	.....	.....	.....	2,000.00	2,000.00
Totals	$15,975.36	$14,473.28	$15,696.89	$38,419.77	$84,565.30

DISBURSEMENTS ON COLLEGE FUNDS

For the Year 1909-1910

Department	Tax	Special	Land Income	Appropriation	U. S.	Total
Advertising	$ 1,405.74	34.70	.....	.....	.....	$ 1.440.44
Agronomy	316.80	75.80	.....	.....	.....	392.60
Animal Husbandry	6,865.81	3,427.07	171.66	.....	.....	10,464.54
Botany and Forestry	70.98	.....	.....	.....	.....	70.98
Campus	721.95	662.04	50.00	.....	.....	1,433.99
Chemistry	421.82	.....	.....	.....	.....	421.82
Civil and Irr. Engineering	1,816.34	18.51	.....	.....	.....	1,834.85
Current Expense	1,677.90	115.62	.....	.....	.....	1,793.52
Electrical Supply	647.91	102.42	20.00	.....	.....	770.33
Farm	3,266.73	5,975.50	713.50	.....	.....	9,955.73
Farm Mechanics	327.05	25.51	.....	.....	.....	352.56
Farmers' Institutes	12.75	.....	.....	6,066.10	.....	6,078.85
Firemen and Janitors	548.00	4,574.60	365.00	.....	.....	5,487.60
Fuel	3,133.51	199.18	.....	.....	.....	3,332.69
General Repairs	1,045.45	10.00	.....	.....	.....	1,055.45
History and Literature	55.20	.....	.....	.....	.....	55.20
Home Economics	1 037.57	101.69	.....	.....	.....	1.139.26
Horticultural	333.21	1,049.26	.....	.....	.....	1,382.47
Insurance	1852.98	.....	.....	.....	.....	1,852.98
Irrigation Building	7,872.70	.....	.....	4,574.80	.....	12,447.50
Land and Water	111.30	.....	.....	3,808.42	.....	3,919.72
Library	1,624.54	6.59	.....	.....	.....	1,631.53
Library Fee	857.09	.....	.....	.....	.....	857.09
Lights	1,046.50	.....	.....	.....	.....	1,046.50

Department	Tax	Special	Land Income	Appropriation	U. S.	Total
Mathematics	.85	1.50	.....	.....	.....	2.35
Mechanical Engineering	4,886.62	18.70	.....	.....	.....	4,905.32
Military	163.55	15.00	.....	.....	.....	178.55
Music	507.59	2.25	.....	.....	.....	509.84
Permanent Improvements	2,547.16	320.00	.....	.....	.....	2,867.16
Physical Training	107.14	16.04	.....	.....	.....	123.18
Physics & Elec. Engineering	2,575.88	11.63	.....	.....	.....	2,587.51
Power	286.30	.....	.....	.....	.....	286.30
President's Office	1,017.99	1.20	.....	.....	.....	1,019.19
Quarterly Bulletin & Report.	941.09	.....	.....	.....	.....	941.09
Registrar's Office	191.97	.....	.....	.....	.....	191.97
Rhetoric and Composition	77.94	.....	.....	.....	.....	77.94
Salaries	17,367.59	1,872 19	8,288.06	.....	40,896.85	68,424.69
School of Agriculture	434.53	3.24	.....	.....	.....	437.77
Secretary's Office	570.57	.....	.....	.....	.....	570.57
State Board of Agriculture	819.65	.....	.....	.....	.....	819.65
State Entomologist	35.20	.....	.....	.....	.....	35.20
Veterinary Science	2,587.87	946.08	.....	.....	.....	3 533.95
Water Assessments	1,197.97	.....	.....	.....	.....	1,197.97
Zoology and Entomology	173.36	8.78	.....	.....	.....	182.14
Bacterilogical	183.54	.....	.....	.....	.....	183.54
Rural Education	85.53	.....	.....	.....	.....	85.53
Farmers' Congress	33.05	.....	.....	.....	.....	33.05
Guggenheim Building	319.20	94.98	.....	.....	.....	414.18
	$74,182.37	$19,690.08	$9,608.22	$14,449.32	$40,896.85	$158,826.84

SUMMARY.

RECEIPTS AND DISBURSEMENTS FOR THE YEAR

1909-1910

COLLEGE FUNDS:	Balance Dec. 1, 1909	Receipts	Disbursements	Balance Nov. 30, 1910
Tax	$33,496.84*	$75,000.00	$74,182.37	$32,679.21*
Land Income	584.95	9,350.00	9,608.22	326.73
Special	3,325.47	16,896.01	19,690.08	531.40
Secretary's Revolving Fund	1,500.00	.....	.....	1,500.00
Mechanic Arts	22,061.41	45,000.00	40,896.85	26,164.56
Appropriation—				
Irrigation Building	15,425,20*	20,000.00	4,574.80	.....
Farmers' Institutes	1,066.10	5,000.00	6,066.10	.....
Land and Water	4,377.77*	8,186.19	3,808.42	.....
STATION FUNDS:				
Hatch	3,559,17	15,000.00	15,975.36	2,583.81
Adams	2,493.84	14,000.00	14,473.28	2,020.56
Special	10.376.46	11,710.17	15,696.89	6,389.74
APPROPRIATION:				
Animal Investigation	1,836.37	5,000.00	6,836.37	.....
Plant Industry	2,589.61	4,000.00	6,589.61	.....
Farm Machinery and Roads	2,216.01	2,500.00	4,716.01	.....
Fruit Investigation	1,012.64	5,000.00	6,012.64	.....
*Potato Investigation	2,673.84	5,000.00	7,673.84	.....
Poultry Investigation	976.83	2,500.00	3,476.83	.....
Horse Investigation	1,385.53	2,500.00	1,114.47	.....
Cheyenne County	1,000.00	1,000.00	2,000.00	.....
Total	$2,587.36	$247,642.37	$243,392.14	$6,837.59

* Overdraft

THE STATE AGRICULTURAL COLLEGE PAY ROLL.

Instructors and Assistants

Annual Salary	Name, Position and Department	College	Station
$4,500	Chas. A. Lory, President	$4,500	...
2,500	Jas. W. Lawrence, Prof. of M. E. and Dean of Faculty	2,500	
3,000	C. P. Gillette, Director and Prof. of Ento. and Zoology	100	$2,900
2,750	Wm. P. Headden, Professor of Chemistry and Geology	200	2,550
1,800	E. B. House, Prof. of Civil and Irrigation Engineering	1,800	
1,600	Virginia H. Corbett, Associate Prof. of English and Lit.	1,600	
2,000	Geo. H. Glover, Professor of Veterinary Science	2,000	
1,600	W. R. Thomas, Associate Prof. Const. Hist. & Ir. Law	1,600	
1,700	B. F. Coen, Professor of English and History	1,700	
1,700	S. L. Macdonald, Professor of Mathematics	1,700	
	H. D. Humphrey, Prof. Military Science and Tactics (Paid by U. S.)		
1,700	G. E. Morton, Professor of Animal Husbandry	1,700	
*1,500	F. C. Alford, Associate Professor of Chemistry	1,500	
1,700	B. O. Longyear, Professor of Botany and Forestry	1,700	
1,700	S. Arthur Johnson, Associate Prof. of Ento. & Zoology	1,600	100
†1,600	Mary F. Rausch, Professor of Home Economics	1,600	
1,600	I. E. Newsom, Associate Professor of Veterinary Sc.	1,600	
1,800	C. L. Barnes, Associate Professor of Veterinary Science	1,800	
2,000	B. F. Kaupp, Associate Professor of Veterinary Science	2,000	
1,200	Sarah I. Kettle, Professor of Modern Languages	1 200	
2,250	AlvinKeyser, Professor of Agronomy—Farm Manager	850	1,400
800	H. E. Kingman, Associate Professor of Vet. Sc. (½)	800	
2,000	L. M. Taylor, Secretary	1,500	500
1,900	E. R. Bennett, Professor of Horticulture	700	1,200
1,800	T. M. Netherton, Prin. of the School of Agriculture	1,800	
1,800	F. A. DeLay, Prof. of Physics and Electrical Eng.	1,800	
§1,500	Inga M. K. Allison, Acting Prof. of Home Economics	1,500	
1,100	Charlotte A. Baker, Librarian	1,100	
500	D. C. Bascom, Assistant, Student Life	500	
1,000	B. G. D. Bishopp, Assistant, Animal Husbandry	1,000	
1,200	Philo K. Blinn, Field Agent, Ark. Valley		1,200
800	L. C. Bragg, Assistant, Ento. and Zoology	600	200
1,000	Zula Brockett, Assistant, English and History	1,000	

* Resigned Dec. 12, 1910.
† On leave of Absence.
§ Acting Head of Department.

1,200	A. Cammack, Assistant, Mechanical Engineering....	1,200	
1,000	G. M. Cassiday, Director, Physical Training.....	1,000	
600	Phebe S. Copps, Assistant, Home Economics.....	600	
900	J. B. Crabbe, Instructor, School of Agriculture.....	900	
480	Arlene Dilts, Assistant, Library	480	
1,500	Earl Douglass, Assistant, Chemistry		1,500
900	Margaret Durward, Instructor, Mathematics	900	
1,000	H. E. Dvorachek, Assistant, Animal Husbandry	1,000	
1,400	C. G. Dwyre, Jr., Accountant	1,400	
400	Anna E. Elwell, Assistant, Physics	400	
900	Alexander Emslie, Director, Conservatory	900	
1,200	Julius Erdman, Florist, Horticulture.....	1,200	
50	Frances Farrar, Assistant, Physical Training	50	
1,500	C. L. Fitch, Specialist, Potato Appropriation		1,500
1,100	D. W. Frear, Instructor, Agronomy	1,100	
1,200	R. S. Herrick, Field Agent, Fruit Investigation		1,200
2,000	C. H. Hinman, Superintendent, Farmers' Institutes	2,000	
200	Alfred Johnson, Electrician, Electrical Department...	200	
1,200	F. N. Langridge, Instructor, Mechanical Engineering	1,200	
1,000	J. D. Marshall, Instructor, Agronomy	1,000	
900	D. H. Mathias, Aid, Irrigation.....		900
850	Miriam A. Palmer, Delineator, Station		850
1,300	R. L. Parshall, Instructor, Civil Engineering..	1,300	
360	D. C. Patterson, Assistant, Veterinary Hospital.....	360	
1,500	J. E. Payne, Field Agent, Plains		1,500
1,300	F. G. Person, Assistant, Physics and Electrical Eng.	1,300	
600	M. Pesman, Assistant, Botany and Forestry.....	600	
1,080	W. A. Peek, Assistant, Farm Mechanics.....	1,080	
1,200	H. Pierce, Instructor, Mechanical Engineering....	1,200	
1,000	Maud A. Propst, Instructor, Home Economics.....	1,000	
1,000	F. J. Rankin, Instructor, Mechanical Engineering....	1,000	
1,000	Annie Robinson, Instructor, Home Economics.....	1,000	
1,900	Walter G. Sackett, Bacteriologist		1,900
1,000	S. Van Smith, Instructor, Horticulture	1,000	
1,000	J. S. Staudt, Instructor, Electrical Engineering....	1,000	
1,100	J. C. Summers, Station, Chemistry		1,100
1,200	R. E. Trimble, Metorologist		1,200
500	C. Agnes Upson, Assistant, Physical Training.....	500	
1,100	C. E. Vail, Instructor, Chemistry	1,100	
1,200	W. E. Vaplon, Poultryman		1,200
540	Ida Walker, Assistant, Library	540	
1,600	G. P. Weldon, Field Agent, Horticulture		1,600
600	Susie Albee, Stenographer, Station		600
720	Daisy Bohnenkemper, Stenographer, Station A. Husb.	360	360
600	Mazie Danford, Stenographer, President.....	600	
900	Margaret Murray, Stenographer, Director		900
900	Julia Reed, Stenographer, President	900	
600	Jennie Short, Stenographer, Registrar	600	

720	Ida Smith, Stenographer, Farmers' Institutes	720	
600	Edith Weldon, Stenographer, Agronomy	600	
600	Nora Zenor, Stenographer, Assignable	600	
600	Colin, Allan, Fireman-Janitor	600	
110	O. Hurich, StudentJanitor	110	
110	A. A. Catlin, Student-Janitor	110	
110	A. J. Calloway, Student-Janitor	110	
110	Lloyd Coon, Student-Janitor	110	
110	R. F. Herdman, Student-Janitor	110	
110	A. Hibner, Student-Janitor	110	
110	O. Hurich, Student-Janitor	110	
900	Wm. Kelly, Head Janitor	900	
110	E. O. Marks, Student Janitor	110	
110	G. S. Ralston, Student-Janitor	110	
600	W. H. Sullivan, Fireman-Janitor	600	
110	J. D. Paxton, Student Janitor	110	
720	J. L. Veasey, Fireman-Janitor	720	
600	J. E. Walker, Fireman-Janitor	600	
720	I. N. Chatfield, Fireman-Janitor	400	320
600	W. H. Marshall, Nightwatchman	600	
600	J. W. Bales, Teamster, Farm department	600	
540	H. J. Brown, Laborer, " "	540	
600	E. C. Coulson, Laborer, " "	600	
540	Fred Coutts, Laborer, " "	540	
540	Thomas Coutts, Laborer, " "	540	
540	J. W. Dallas, Laborer, " "	540	
720	J. Dalrymple, Laborer, " "	720	
600	James Fraser, Laborer, " "	600	
600	Alvin Fry, Irrigator, " "	600	
540	C. S. Grundy, Laborer " "	540	
540	E. L. Grundy, Laborer " "	540	
600	S. J. Lawson, Laborer, " "	600	
600	Wm. Munn, Laborer, Horticulture	600	
720	Alex. Nicholson, Herdsman, Animal Husbandry	720	
1,200	Wm. O'Brien, Superintendent Farm, Farm Department	1,200	
540	J. M. Portner, Laborer, Farm Department	540	
600	S. S. Portner, Laborer, Farm Department	600	
600	Wm. Thompson, Herdman, Animal Husbandry	...	600
240	Adam C. Auld, Assistant Groom, Horse Invest	...	240
600	A. T. Barnhart, Laborer, Agronomy	600	
120,760	Total	$95,800	$26960

THE STATE BOARD OF AGRICULTURE:

Gentlemen.—In presenting to you this, my annual report, I must of necessity cover many of the subjects presented to you in the semi-annual report last June. The work of instruction on the campus falls naturally in the year beginning June 1st and ending May 31st, and the June meeting is the best time for receiving reports of progress, of needs, and of achievements in the educational work done on the campus. It is also the natural time for allowing the budget of expense for the following school year and for making the necessary plans for whatever repairs and new work that is to be done on the campus during the summer months. For this reason much of the material that was presented to you in the semi-annual report last June you find embodied also in this report.

A Year of Organization.—The past year has required many changes in our general organization, made necessary by the growing importance of extension work, by the many demands upon the Experiment Station, and by the desire on the part of your Executive Committee, the Faculty and myself for greater efficiency in the educational work at the College. The first result of these changes in organization is the increase in the work of your Executive Committee. For years the Committee has confined its work to making a monthly audit of the expenditures, while the many matters relating to the administration, such as finance, faculty and courses of study, college lands and leases, college buildings and permanent improvements, farmers' institutes, the work and the needs of the several departments, were the subjects of recommendation from special committees of the Board. We have found it almost impossible to secure meetings of these special committees during the half-year interval between the semi-annual and annual meetings of the Board of Agriculture, and the practice, by special committees, of asking the Executive Committee, which meets monthly in a one or two days' session, as the volume of business requires, to take care of their special work, has increased until now practically all work of the Board between regular meetings is done by the Executive Committee. In order to keep all members of the Board advised on the work of the Institution an abstract of the minutes of each meeting of the Executive Committee is made out by Secretary Taylor and mailed to each of you, with a letter of general information, by myself. Nothing has done so much to facilitate work and make possible effective administration as this desire of the special committees to refer their work to the Executive Committee, and the willing-

ness of the latter to give much time each month to the many problems incident to our various lines of work.

Gradually, then, we have come to look more and more to the Executive Committee as the representative of the Board in all matters of administration, and we have built up our organization on the plan of referring to its monthly meetings questions of administration and of general policy. In building up our organization we have many problems confronting us. To the three main lines of work of the land grant colleges; first, the training of specialists and of practical workers, in Agriculture, Mechanic Arts, and Household Arts; second, research and investigation in agriculture, and, third, extension work by means of correspondence, lecture courses, institute trains and demonstration experiments in all parts of the State, we have added the problem of administration of a large farm under intensive cultivation, and through recommendations to the State Land Board of the grant of 90,000 acres of land, given the State as an endowment for the College when the provisions of the Morrill Act were accepted by our Legislature.

The training of specialists and of practical workers in Agriculture, Mechanic Arts, and Household Arts in strictly educational. High efficiency in this line of work requires that the teacher be well trained; that he have ability in giving instruction; that he make teaching his main work, that he be interested in his classes; that he have time to look after the lagging students and time to keep in touch with the advancement in his specialty. This will not allow much time for investigation or for extenson work during the school year. Research and investigation work in the Experiment Station require a man well versed in his specialty, a man able to think independently and to interpret laboratory data. His success largely depends upon his freedom from interruption, upon the possibility of giving his undivided attention and time to his investigations, and upon reasonably good working facilities and considerable freedom for personal initiative in the planning of his project and the publication of his results. If he is to give time to teaching, it should all be confined to one semester, when his service can be best spared by the Station, and if he is to do extention work, this should largely be along the line of his research at the time. Work in college and station extension calls for special training and for qualities on the part of the worker different from either those of the teacher or of the investigator. He must have the gift of teaching, but must be able to accommodate his mode of presentation to a constantly changing class; he must be able to take the lectures of the specialist at the College and the data of the investigator in the Experimnet Station, and, modify both, present them in such a way that they can

be understood by his audience and incorporated into their daily practice. He must be able to carry on demonstration work and teach by actual example the value of new methods. His work naturally is in the field, among the men engaged in agriculture, and in the industries. To withdraw him for long periods, either for teaching or for research work on the campus, cuts down his efficiency.

When the attempt is made to carry on these three lines of work, which differ so fundamentally from one another, with the same corps of men, difficulties multiply at once. The needs of his classes prevent the teacher from doing much station or extension work during the school year, and the efficiency of the station worker is cut down if he must spend too much time in the field or in the class room. The extension work suffers at once if the worker is withdrawn for any considerable period from the field and put to work in class rooms or investigations and good team work and helpfull co-operation among the workers in the three lines require that each be well informed of the work of the other two. Moreover, a certain amount of extension work should be done by both teacher and investigator; it places them in touch with actual conditions in the field, with the problems of the producer, and makes them familiar with the producer's point of view. A certain amount of teaching and investigation should be done by the extension worker, because it puts him in touch with the work of instruction and investigation.

Proper organization, then, should provide for a certain exchange between the work of the teacher, the man engaged in research, and the extension worker. It should provide for good team work and for the opportunity to plan work for several months in advance, and it should make possible high efficiency in all three lines of activity. Proper organization must also provide for meeting the demand of more extension work, which the needs of our State make imperative, and provide for the increased demands upon the Experiment Station and upon the educational work at the College which will naturally follow the increased activity in extension work.

In working out our plan of organization we made an extensive study of the systems used by the colleges and universities of the middle West, and were fortunate enough to hear the discussion of college organization, with relation to extension work, at the Graduate School, at Ames, Iowa, this summer. Bringing the information gleaned from the experience of others to bear on our own problem, it was not thought desirable to establish a separate corps for extension work, even should we have the funds to do so.

The plan of making the Experiment Station worker entirely independent of the College department has never seemed advisable and as research work increased, certain departments were organized for instruction and for investigation, men being assigned to one or the other line of work as its needs made necessary. The work was planned so as to free the teacher for the time being, as far as possible, from station work and vice versa. A scheme of organization, based upon this plan and modified so as to include extension work, was finally adopted by the Executive Committee. This scheme provides that all departments in the College shall be organized for instruction, for research and for extension work. Full work in these three lines will require that a department have a number of workers for teaching, a number of workers for research and a number of workers for extension. It is not expected that a department like Mathematics, English and History, Modern Languages, etc., shall do station work, but answering the call for help from the public schools, there is no reason why these departments cannot do valuable extension work in their respective lines.

The department is made the unit of organization. The worker in teaching reports through the head of the department to the Dean of the Faculty. Those engaged in investigation report through the head of the department to the Directir of the Experiment Station, and the extension workers report through the head of the department to the Superintendent of Extension Work. The Dean of the Faculty, the Director of the Experiment Station, and the Superintendent of Extension Work report to the President, who reports directly to the Executive Committee of the Board, which Committee in turn reports to the full Board at the annual and semi-annual meetings. Monthly reports and estimates of expenditures for the coming month are made to the President by the three executive officers, the President in turn submitting his report and a general estimate of expenses to the Executive Committee at its monthly meeting. The Dean, the Director, and the Superintendent meet at the call of the President for consultation on questions of general policy and with the President and Executive Committee, for conference at the monthly meeting. Projects for research work must be submitted to the Director for his approval before any investigation is started, and plans for extension work must be approved by the Superintendent and the work done in the field under his direction. The plan of organization is shown in the following outline:

The Executive Committee of the Faculty.—The general routine work of the Faculty is done by the Executive Committee of the Faculty, made up of the Dean of the Faculty, the chairmen of the divisions of Agri-

culture, Mechanic Arts, General Science and Home Economics, and Veterinary Science, the Principal of the School of Agriculture, the Chairman of the Committee on Rural and Industrial Education, the Chairman of the Committee on Courses of Study and Catalogues, and the chairman of the Athletic council. The division of Agriculture comprises the departments of Agronomy, Animal Husbandry, Chemistry, Entomology, Farm Mechanics, Botany and Forestry, and Horticulture. The division of Mechanic Arts is made up of the departments of Civil and Irrigation Engineering, Electrical Engineering and Physics, Mechanical Engineering, and Mathematics. The division of General Science and Home Economics is made up of the departments of English and History, Modern Languages, and Home Economics, and the division of Veterinary Science of the various parts of the department of Veterinary Science.

The chairman of each division is responsible for the students of the division and for general division interests. General division and weekly departmental meetings are helpful in securing good team work.

The Experiment Station Council.—In order to secure effective co-operation and good team work among the workers in experiment station lines, the Station Council, made up of all men who are carrying on projects under the Adams and the Hatch funds or special appropriations made by the State Legislature for experimental purposes, has been organized and meets at the call of the Director for the consideration of general Experiment Station matters and policy.

Council of Extension Workers.—Our extension work has not yet developed sufficiently to warrant the organization of a special council for the extension workers. Should more appropriation be provided by the Legislature for this line of work, so that a greater force can be employed in the several departments for the extension work, such an organization will be necessary.

Changes in the College Courses.—At present many of the class rooms must be used both by the college and the School of Agriculture classes at different times in the day. When the college year was divided into three terms, of twelve weeks each, the School of Agriculture, opening in October and closing in April, overlapped both the fall and the spring terms, making it very hard to adjust classes at the close of the fall and winter terms and at the close of the first term of the School of Agriculture. To avoid this the college year was divided into two semesters, so that the first semester in the college work and the first term in the School of Agriculture work end practically at the same time, and the courses in the college arranged accordingly. A further change in the course

of study made the first two years for all courses in the division of Agriculture alike, the first two years for all engineering courses in the division of Mechanic Arts alike, and the first two years in the courses in General Science and Home Economics alike. Ten hours of electives are allowed in all four-year courses in the Junior, and twenty hours in the Senior year, and the requirements for graduation were made the same in all four-year courses. One hundred and sixty semester credits, six of which must be in military drill, for men, and in gymnasium work for women. Women are allowed to present five credits in Music; 145 semester credits are required for graduation in Veterinary Science, four of which must be in military drill.

Farriery and Two-Year Course in Mechanic Arts Discontinued.—Neither the course in Farriery nor the two-year course in Machanic Arts was well patronized, the former having no students enrolled last year. By action of the Executive Committee both were discontinued, the Farriery course in January and the Mechanic Arts course in June.

Salary Schedule.—At the semi-annual meeting, 1909, you appointed a committee to work out a salary schedule, especially for the workers engaged in teaching, and requested this committee to report at the annual meeting. At the annual meeting the committee reported progress and asked for more time. At the semi-annual meeting, in June, 1910, Chairman Ammons reported that it had been very difficult for him to get his committee together and that he was not yet ready to report. The question of salaries, therefore, was referred again to the Salary Committee, with instructions to report to the Executive Committee and at a special meeting in June, the report of the Salary Committee was adopted, and the schedule of salaries proposed accepted and ordered put into effect beginning with September 1st, of the past year.

Changes in the Faculty.—Librarian Joseph F. Daniels, presented his resignation at your last annual meeting and left his work here December 31, 1909, Miss Charlotte Baker was appointed Acting Librarian until June, and Librarian at the June meeting. Miss Daisy Frink, assistant in the Department of Mathematics, resigned in December. Mr. James Pennycook, Assistant in Farriery, severed his connection with the Institution in January. Instructor E. J. Iddings, of the Department of Animal Husbandry, resigned in May to accept a position with the University of Idaho. H. M. Cottrell, Director of Farmers' Institutes and Extension Work, presented his resignation to the Executive Committee at its May meeting in order to accept a position with the Rock Island Railway Co., as Agricultural Commissioner. Director Cottrell had been with us four years and did great service for the State. Though we rejoice in his good for-

tune, all of us keenly regret the loss of his valuable services to the Institution and to the State at large. Director L. G. Carpenter presented his resignation as Director of the Experiment Station at your semi-annual meeting last June. In order to meet Director Carpenter's request to be relieved of the duties of his office as soon as possible, the Executive Committee appointed me Acting Director until the new Director could be appointed and take over the duties of the office. Prof. C. P. Gillette of the Department of Entomology and Zoology, was appointed Director of the Experiment Station, at a special meeting of the Executive Committee, June 14th, but did not take over the work of the office until the beginning of the new fiscal year, July 1st. Prof. Carpenter told the Committee that it would not be possible for him to give all his time to the work of the Institution. The Committee therefore relieved him of all instructional work in the Department of Civil and Irrigation Engineering, so that he could give his time entirely to Station work. H. M. Bainer, Professor of Farm Machanics and Dairying, and Farm Manager, resigned in June to accept a position as Agricultural Commissioner with the Santa Fe Railway Company. It was found impossible to find a man to take Professor Bainer's work, so the dairy work of his department was transferred to the Animal Husbandry Department. Professor Keyser was appointed Farm Manager and Mr. H. B. Bonebright placed in charge of the work in Farm Machanics. The position of Mr. D. E Mackey, instructor in Forge in the Department of Mechanical Engineering, was declared vacant by the Executive Committee at its special meeting June 14th. Mr. Claude Rothgeb, Director of Physical Training, resigned in June to accept a position with Colorado College, Colorado Springs. Leslie F. Paull, Associate Professor of Horticulture, severed his connection with the Institution, in August. Professor Mary F. Rausch, of the Department of Home Economics, who has not been well for some time past, was forced to give up her work entirely in October for an extended rest. She will spend several months in Europe and is not counting on taking up her work again before next year. She was granted a leave of absence for a year, if necessary, by the Executive Committee, with the understanding that when she returned to the College most of her time should be given to extension work. Edward A. Bessey, instructor in the Department of Physics and Electrical Engineering, died suddenly June 12th. His death was wholly unexpected and came as a great shock to the Faculty and the students alike. Mr. Bessey had been with us only a year, but in this time he had securely won the respect of his associates and the confidence and friendship of all of his students.

Promotions.—E. B. House, associate professor in Civil and Ir-

rigation Engineering, was promoted to Professor of Civil and Irrigation Engineering. Ralph Parshall, instructor in the Department of Civil and Irrigation Engineering, and Fred G. Person, instructor in the Department of Physics and Electrical Engineering, were promoted to assistant professors. H. B. Bonebright, assistant in the department of Farm Mechanics, was promoted to instructor.

New Appointments.—Claude H. Hinman, B. S., University of Nebraska, and a member of the Extension Division in the Kansas Agricultural College, was appointed Superintendent of Extension Work, in June, to succeed Director H. M. Cottrell. Superintendent Hinman took up his duties with us August 1st. Inga M. K. Allison, head instructor in the Department of Home Economics last year, and granted leave of absence for a year, by the Executive Committee, in June, was appointed acting head of the Department of Home Economics when Miss Rausch had to give up her work in October. H. E. Dvorachek, B. S., University of Minnesota, was appointed instructor in Animal Husbandry, April 29th, to take the place made vacant by the resignation of Mr. Iddings. Mr. Dvorachek entered on his duties here July 1st. Margaret Durward, Ph. B., Chicago University, was appointed assistant in the Department of Mathematics, June 28th. Mr. S. V. Smith, B. S., Kansas Agricultural College, was appointed instructor in the Department of Horticulture at the same meeting. B. G. D. Bishop, B. S., C. A. C., was appointed instructor in Dairying in the Department of Animal Husbandry, J. F. Staudt, B. S., A. M., Franklin and Marshall College, was appointed instructor in the Department of Physics and Electrical Engineering. F. J. Rankin, B. M. E., University of Kentucky, was appointed instructor in Forging in the Department of Mechanical Engineering. Michiel Pesman, B. S., C. A. C., was appointed assistant in the department of Botany and Forestry. Anna Robinson, B. S., Teachers' College, Columbia University, and Maud Probst, B. S., Rockford College, Rockford, Ill., were appointed isntructors in the Department of Home Economics. Pheobe Copps, B. S., Armour Institute, was appointed instructor in Home Economics for work in the School of Agriculture. J. B. Crabbe, B. S., Ohio Wesleyan University, was appointed instructor in the Department of English and History for work in the School of Agriculture. James D. Marshall, B. S., University of Wisconsin, was appointed instructor in the Department of Agromony. George D. Cassidy, B. A., University of Vermont, was appointed Director of Physical Training, and D. C. Bascom, B. S., Kansas Agricultural College, Secretary of the College Y. M. C. A., was engaged to give half his time to the student life work of the Institution

Enrollment.—A study of our enrollment this school year, fur-

nishes much food for thought. When we were planning our campaign for new students last spring we set our mark at three hundred for the College and four hundred students for the School of Agriculture. While it was not possible for us to conduct nearly so vigorous a campaign as we wished on account of lack of funds, yet we tried to speak before high schools in the State at least once and some more than once. However, the results show that our work was not effective enough and that we did not put ourselves and our work before the high school students sufficiently to turn them to us in as large numbers as we are entitled to or have reason to expect. The work done by Miss Rausch and by Professor House before the high schools bore excellent fruit. No one who has not had actual experience in this field knows how strong the competition for students is in this State. In Agriculture we have no competition, but the high school boys do not as yet understand the great opportunities that are offered in this field of endeavor, so that very few are looking toward some branch of agriculture for a vocation. Neither do the young women of the State realize the great demand that is bound to come for teachers in agriculture and domestic science, so that the young women of the high schools who are looking toward a teaching career naturally think of the Normal School, first, or, if they expect to teach in a high school, many of them look to the University. When it comes to Engineering, quite a number of high school graduates go out of the State. Those that remain here have the choice of three institutions; the University, Colorado College, and our own Institution, if they desire to take either Mechanical, Electrical, or Civil Engineering. The strongest work in Irrigation Engineering must naturally be with us, and I think we should look with considerable disfavor upon the efforts of any other state institution toward the establishment of such a course.

The very fact that we are a technical school; that our graduates do not enter the teaching profession, but go into the industries where they are not in touch with great numbers of young people, especially high school students, while the other institutions that have engineering schools, also have a Liberal Arts course where quite a number of teachers are prepared annually, these teachers going into the high schools of the State and naturally working, perhaps unconsciously, to turn the minds of the graduates to their own Alma mater, gives these institutions an advantage in the solicitation of students, for it can hardly be expected that one of our teachers visiting a high school, speaking perhaps for half an hour or fory minutes once a year, can have as much influence in directing the students here as can the teacher who is with the class constantly and by her very efficiency and popularity makes a strong impression for the institution that

trained her. We must have students here if this Institution is to give the service the State has a right to expect. A splendid plant has been established here; a splendid Faculty has been gotten together. We have the facilities for taking care of more students than we have now, especially since we have gotten the two new buildings that have come to us this past year. It is just as easy to teach a class of twenty or thirty as it is a class of three, and every young man that we can graduate and send back to the industrial work of the State carries the work of the College to his community far more effectively than we can do through our extension work. The following table will show our enrollment to date, also what percentage of students of last year's classes returned to the College this fall.

	Men.	Women.	Total.
College Students	179	62	241
School of Agriculture Students	188	85	273
Conservatory of Music	20	57	78
Returned to College this fall:			
Unclassified Students			30%
Freshmen			68%
Sophomores			83.6%
Juniors			86%
Returned to School of Agriculture			56%
College Graduates Last Year			42
Non Resident College Students			27
Non Resident School of Agriculture Students			19
Number of Accredited High Schools Not Represented			23
Number of Counties not Represented			27
Number of Counties Not Represented in School of Agriculture			16

Conference of Presidents of the Four Institutions of Higher Learning.—Early in the year Govenor Shafroth issued a call to the Presidents of the four institutions of higher learning for a conference to be held in his office, on the 19th of February, to consider the question of cutting down expenses of the several institutions, and particularly to consider the question of duplication of courses. Senator Ammons was requested to meet with the presidents and to take part in the discussion. The whole question of cutting down expenses at the several institutions was gone over and the question of duplication of work taken up. It was shown by President Victor C. Alderson that the School of Mines is confining itself entirely to the teaching of courses in Mining Engineering and Metallurgy and that no other courses in Engineering are attempted or contemplated, and in its main courses the School of Mines is duplicating none of the work of the other institutions. A certain amount of duplication

was found between the State Normal School and the State University, in the department of Education, and between the University and the Agricultural College, in the courses in Engineering. No satisfactory method to avoid duplication could be worked out; in fact the conference could not agree that this was altogether desirable. A committee was appointed, with Senator Ammons Chairman, and the Presidents of the Institutions of Higher Learning to look into the matter and report to the Governor later. At a meeting of this committee later the School of Mines, the Normal School, the Agricultural College could agree upon a line of work, but the University Regents, through President Baker, declined to consider this plan. Since then no meeting has been held and no report was ever made to the Governor. This conference has a great opportunity, and if it should be possible for it to outline the function of each institution so that the four can work together as an efficient, well organized educational machine, each taking part of a certain share of the work, it will be the greatest achievement possible for education in Colorado and will furnish the possibility for each and every one, no matter what institution he attends, to be a loyal supporter, not only of his own, but of all the State. institutions. As soon as the true function of each school is thoroughly understood by the public it will be easy to secure adequate appropriations, and each school can adapt itself to carry on its particular work in the most economical and efficient manner possible. It is unfortunate that this has not been done before, but we are in the same position as practically every other state in the Union where the Agricultural College is separate from the State University, with possibly two exceptions. The separate Universities are following, as closely as they can, the Universities of the states where the Agricultural College is a part of the State University. They feel that the range of subjects that they are allowed to teach should not be limited; that, being a University, they can branch out and cover the entire field of human thought. In this they are encroaching more and more upon the work of the Agricultural College as outlined in the original Morrill Act and as specified by the Commissioner of Education. This has led to increasing duplication of work and bitter rivalry between the institutions.

As a Board we have been criticised for duplicating the engineering courses of the State University, when as a matter of fact, engineering courses there were established after our own. Not only that, we at this Institution must live up to the contract between the Legislature and the Federal Government, entered into when the Agricultural College was started. Under this contract Military Science, Agriculture and Mechanic Arts must be taught. The fault of duplication rests with the Legislature when funds were appropriated for es-

tablishing the School of Applied Science, later developed into the College of Engineering at the University, after the Government had provided funds for maintaining this work at this Institution. If the people of the State, through the Legislature, wish to maintain an engineering school at the University, we can find no fault, but in maintaining engineering work here we are only living up to the contract entered into by the Legislature whose terms we as a Board are responsible for carrying out.

Conservatory of Music.—On account of lack of room it was found necessary to rent four extra rooms down town last year for the use of the Conservatory of Music. The plan was not at all satisfactory because it took the Conservatory students away from the campus. At the opening of school this fall the Conservatory of Music took up its quarters again on the campus and is permanently housed in the old Domestic Science Building.

Student Life Work.—During the year considerable attention has been given to the student activities outside the class room. Miss Corbett, as Adviser of Women, and as Chairman of the Social Committee, has helped the young women in finding satisfactory homes, has kept in close touch with them through weekly conferences and through visits at their homes. By the establishment of a social calendar where the dates of social meetings are posted after a conference with the Chairman of the Social committee, the plan of confining all social meetings to the week end has been helped and a better regulation of the social life of the Institution made possible. By agreement between the College and the Young Men's Christain Association a part of the Secretary's salary is paid by the College, so he takes charge of the work of helping men find rooms and board, of directing the student labor bureau, and of helping the men generally in the problems of the daily College life. He also takes charge of some teaching in the School of Agriculture during the second term. The Physical Director is giving a great deal of time to the men outside of athletic activities, and by his influence is stimulating their ideals of courage, right conduct, good scholarship and fair play. Professor Macdonald, as Faculty Treasurer of the Athletic Association, has been able to do much good by wise counsel and helpful suggestion in athletics and other lines of student activity. In fact the entire Faculty has taken a keen interest in the work of the student outside the class room, and we have good co-operation between Faculty and students that works strongly for increase in the efficiency of instruction.

Some progress has been made in student self-government, in both the College and School of Agriculture, and the manner in which the students are working out their problems is gratifying and encouraging.

The Young Men's Christain Association is strong and vigorous and exerts a powerful influence for right living. No less in scope and effectiveness of service is the Young Women's Christain Association.

Our technical and literary societies receive good support and afford excellent training in problems of administration, in the preparation of technical and literary papers, in parliamentary practice and in public speaking.

The Budget.—Last year we started the budget system for all departments of the College. This year the plan was extended to cover the work of the Experiment Station. The extension work has its funds practically set by appropriation from the legislature, although both the strictly educational funds and the special appropriations for experimental work made by the legislature, contributed for extension work. The railroads of the State, also, through their generosity in transportation for men and materials, and in their granting of institute trains, have given nearly as much as the amount appropriated by the legislature for farmers' institute work. Were it not for this help from the railroads and the help from the other funds, the five thousand dollars per annum annual appropriation made by the last legislature would be wholly inadequate to meet the needs of extension work.

The State fiscal year closes November 30th, the government fiscal year June 30th, for the educational work on the campus it is far more convenient to make the estimates for the school year closing almost forced to follow the reciation or catechetical method of teach- June first than for the year ending November 30th. This introduces some difficulties in bookkeeping and unless the rate of expenditure is specified, the tendency on the part of heads of departments to spend their allowance as rapidly as possible will cause an overdraft on the funds by the end of the fiscal year. No matter how carefully an estimate may be prepared, there are so many uncertainties in the matter of enrollment, repairs, fuel needs, calls for special work, etc., that a large contingent fund is a necessity. The most difficult problem of all in making out the budget for instruction, experiment station and for extension work is met in the special appropriation for farmers' institutes, for special demonstration or experimental work. The funds must be used by the end of the fiscal year, but many lines of work can not be discontinued November 30th and held in abeyance till the new appropriation is available. Well trained men for both extension and research work are not only scarce, but are in strong demand. It is hard to hold good men against the higher salaries paid by older and richer institutions. It is simply out of the question to expect men to wait from the end of the fiscal year till the new appropriation is available without salary. Moreover, the nature of

the work is such that such a wait would often mean the loss of an entire year. This unfortunate condition makes it necessary for the Board of Agriculture either to discontinue these lines of special inquiry at the end of the fiscal year, and then start in again with such men as may be secured when funds are again available, or to continue until the Legislature shall again provide funds for the work. This, however, puts an undue burden on the educational funds and makes them assume the loss should the Legislature not consider it advisable to continue a certain line of work. The special fund of the Experiment Station, which consists of money derived from the sale of products grown and animals fed for demonstration or experimental purposes, is used for this purpose, also, but is usually not sufficient. In making out the budget, allowance is made for the purchase of material and labor by one department from another and from the farm; in other words for the full cost of the department in every case. The departments are credited with the funds thus received, but are not allowed to disburse them. This plan is used because we have as yet insufficient data to make a good estimate of this departmental income.

Improvements.—At the June meeting of the Executive Committee, Prof. J. W. Lawrence was appointed Superintendent of Buildings. He began at once a vigorous campaign of general repairs and improvements. The janitor force was organized and used in making repairs, in oiling floors, painting and varnishing. Prof. E. B. House, and Assistant Professor Ralph Parshall, spent the entire summer in fitting up the laboratories of the new Civil and Irrigation Building. The splendid facilities we now have for laboratory work in irrigation engineering are largely due to their efforts. The old Civil Building was remodeled for the Department of Physics and Electrical Engineering. Cement floors in the basement, the papering, painting of wood work, oiling floors, and repairing of walls and painting outside wood work and roof have transformed this into one of the neatest buildings on the campus. The forge room at the Mechanical Building was enlarged to accommodate forty forges, and the necessary increase in anvils and forges ordered. Delay in securing the last prevented the completion of work of installation before the opening of the School of Agriculture. Enough new benches and tool sets were purchased to bring the total capacity of the wood working room up to forty students, and the Electrical Engineering laboratory was moved from the Mechanical Building to the basement of the Electrical Building. More coal and general storage capacity was provided for the Mechanical Building by building a 20-foot addition to the old storage shed west of the foundry.

Provision had to be made to connect the heating system of Simon

Guggenheim Hall of Household Arts to the boiler in the Mechanical laboratory. This is a vacuum system, while a low pressure steam system has been in use in the Mechanical Building and Library. It was thought best to change this to the vacuum system, the saving in fuel warranting the extra outlay of a thousand dollars. Provision had to be made also for a hot water heater and tank for the Household Arts Building, and cooking tables for the foods laboratory in this building. The drugroom was enlarged at the hospital and a ward built for small animals.

The experimental driveway built under the direction of Mr. J. H. Dodge, of the Good Road Division, United States Department of Agriculture, furnishes a good example of what can be done in road building, with native material, and is a splendid addition to the campus. The grading around the Household Arts and the new Civil and Irrigation Engineering buildings has been completed and the ground gotten ready for seeding to lawns in the spring.

New Buildings.—The new Civil and Irrigation Building was ready for use last February. Furniture and equipment have been provided for class rooms and laboratories. The building proves to be especially well designed for its purpose.

Simon Guggenheim Hall of Household Arts is a splendid monument to the generosity of Senator Guggenheim. The building was ready for use by the middle of November. It proves to be well adapted for the work and has relieved congestion that was almost unbearable. Equipment sufficient to meet classes has been installed, but much more is necessary.

Insurance.—An effort has been made to reduce the fire risk on the campus, to increase the efficiency of our protective apparatus, and to develop a fire fighting organization among our employes. We have made progress and have gotten some reduction in insurance rates.

Administration of the Farm.—Beginning March 1, 1910, the plans worked out by Prof. H. M. Bainer, as Farm Manager, for the administration of the Farm were put into effect. Under this plan each workmen fills out a time sheet on which he tells what he is doing and where, for each hour of the day. A map was prepared of the Farm and each field numbered. Each field is charged with labor, seed and fertilizer. A schedule of prices was arranged for man labor and horse labor, and whatever is done for other departments in the way of labor or for improvements about the campus is charged to the department or to the campus and the farm given credit. Any feed, grain or other products grown on the farm and gotten by other departments, is charged at current market prices, and the farm pays for what it receives in the way of services, such as veterinary

service, surveying, or other work furnished by the other departments. Keeping these farm accounts has added a very heavy burden to the clerk of the Department of Agronomy and to the Secretary's office, and yet we believe it is worth while, because after a time it will be possible to take these accounts and to show exactly how much it costs the farm to produce a ton of hay or a bushel of grain. It gives us at all times a definite idea of how much the farm is costing us—how much it is earning for the institution. Plans are now under way for working out a definite rotation for the farm, and to extend the system of charging to include water as well as labor, seed and fertilizer for each field in determining the cost of production; we will also determine the duty of water and be able to include the value of it in the cost of production for each field.

Visits to Other Institutions.—During the last year we have gradually developed the policy of sending some of our men to study the methods of other Institutions. This was inaugurated by Senator Ammons, who, at heavy expense to himself, took a trip to Washington last winter and on his way back visited a number of the institutions in the middle West. His knowledge gained at first hand, of the methods and plans of these were so helpful in his work on the Executive Committee here that it was decided to have our men follow his example whenever possible.

I spent three week last summer as the guest of the Agricultural Commissioner of the Rock Island Railroad, visiting the Agricultural Colleges and Universities in the middle West. This fall Dean J. W. Lawrence spent a month studying the heating plants, shops, equipment, methods of administration and general student life of some of the middle West and eastern colleges, and last month Director C. P. Gillette, Superintendent C. H. Hinman, and myself, attended the meeting of the American Association of Agricultural Colleges and Experiment Stations, at Washington, where we had the privilege of meeting workers in our respective lines from all over the country and listening to discussions of vital problems in general college, experiment station and extension work, administration methods, and policy. These visits give a broader view, they give a first-hand knowledge of what other institutions are doing, they give the opportunity of direct comparison between ourselves and others, the study of methods better than our own, and make possible the adaptation of these to our own conditions. I hope this policy can be continued, I know of nothing that will do more for the general work of the Institution than to have its men make occasional trips to the leading institutions of our country.

Experiment Station.—The work of the Experiment Station has responded in a most gratifying manner under the stimulus of increased appropriation. With all our increased activity, however, the

demands upon the Station are far beyond its ability to supply. The accompanying report of Director Gillette shows how much has been accomplished this year.

College Extension.—The great amount of extension work that we have been able to do is the best evidence of effective organization on the campus and of the strong co-operation between the College and all the organizations and workers who are interested in the agricultural and industrial development of Colorado. The report of Superintendent C. H. Hinman shows you how much has been accomplished and how varied and extensive the extension activities of the college have become.

Needs.—The needs for the next biennium have been thoroughly gone over, conferences have been held between the various parts of the College and the needs of the work on the campus, of the Experiment Station and of the Extension thoroughly considered. Conferences have also been had with various organizations and the needs of various industries and sections taken into account with the result, a bill to be submitted to the next Legislature has been drawn up and is submitted for your consideration. The amount asked for has been made as conservative as possible. We do not believe in the plan of asking for double as much as we expect to get. We want to go before the Legislature with a straight, open, business-like statement, showing just what has been accomplished the past two years, what the needs of the various industries are and what we hope to accomplish with the amount asked for the next two years and we hope the Legislature will treat us in the same way and if possible pass the bill without cutting down a single section.

Appreciation.—This report would not be complete without expressing my appreciation to the entire Board for the help you have given me during the past year. To the members of the Executive Committee, for their efforts in behalf of the Institution; to Dean J. W. Lawrence, Director Gillette, and Superintendent Hinman, for their untiring efforts in behalf of their special lines of work and for the splendid spirit of mutual help and co-operation they have shown; to Secretary Taylor and Accountant Dwyre, whose initiative, ability and willingness to take on new work have made it possible for us to tell now at the end of each business day how every fund and budget account stands, to the Executive Committee of the Faculty and other workers as a whole. We have all worked hard, we have pulled together, we have enjoyed the day's work, and have striven to make it result in higher efficiency and in making our Institution of greater service to the State.

Respectfully submitted.
CHAS. A. LORY, President,
State Agricultural College.

REPORT OF THE DEPARTMENT OF AGRONOMY.

To the President:

Prior to the beginning of the school year, 1910-1911, the Agronomy courses were thoroughly revised. The object of the revision was twofold. First, the school year was changed from a three term to a semester basis, which change made necessary several readjustments in the courses. Second, changes in state conditions and personnel made it advisable to adjust to the new problems to be met. As revised, courses are offered in Crop Production, Soils, Crops Laboratory, Soils Laboratory, Advanced Farm Crops, Farm Management, Plant Breeding, Agronomy Seminar, or Special Problems in Agronomy, Soil Fertility Laboratory.

The change from a three term to a semester basis permits much better arrangement of time. The student is kept in contact with the subject for a longer period. The arrangement also gives both student and teacher more time for preparation. Thus we are able to require, of the student, more preparation outside the class room.

The Department is teaching Crops, Crop Production, Soils, Soils Laboratory and Farm Management in the School of Agriculture.

To more effectively teach these subjects in the College and in the School of Agriculture, the teaching force has been increased by employing Mr. J. D. Marshall, a graduate of the University of Wisconsin. Thus the teaching staff now consists of Alvin Keyser, Professor; Mr. D. W. Frear, Instructor, and Mr. J. D. Marshall, Instructor.

Mr. Frear is at present teaching the class in Farm Management in the School of Agriculture. The rest of his time is entirely given to college classes. Mr. Marshall is devoting practically his whole time to classes in the School of Agriculture. It is thought that this specialization of the instructor's time, i. e., having the instructor devote nearly his entire time to either the School or College will give higher teaching efficiency, and the results so far bear out this opinion.

Since the last report the room above the chapel has been assigned to this Department for the School of Agriculture classes. This change has enabled the Department to provide materials and equipment especially adapted for the two different classes of students, School and College.

This room permits larger classes. Thus, although the registration and number of classes is larger this year than last, we can handle the larger number with less friction than last year.

New equipment, which will increase the efficiency of the work, will be installed during the year in both the crops and soils laboratories.

The total number of students taking work in the Department, at present, in the School and College, is 153.

Aside from the regular teaching work on the campus, the Department has done considerable extension work. The extension work has consisted of articles written for "News Notes," farmers' institute work, lectures to teachers' institutes, preparation of courses of study and outlines for agricultural instruction in rural schools, and help furnished in judging, lecturing, etc., for boys' and girls' clubs.

Mr. Frear has supplied six articles for "News Notes." He lectured four weeks before teachers' institutes. He spent between two and three weeks in preparing "Outlines and Exercises for Elementary Agriculture for Rural Schools." It is expected that this material will be used by the State Superintendent of Public Instructon in the rural schools of the State, and he judged the exhibits of two special and one general boys' and girls' club exhibit.

I furnished eleven articles for "News Notes," one of which was published as a thirty-two page special edition of "News Notes." In addition I attended nine farmers' institutes, two farmers' picnics, two fairs, and gave ten special short course lectures.

About two thousand letters, furnishing information of a general and technical nature, have been sent out to farmers of the State.

Mr. Payne, of the experimental staff of the Department, has delivered about fifteen farmers' institute lectures. He has also addressed a number of special farmers' meetings and given addresses at fairs. He has also done almost all the department judging and lecturing for the boys' and girls' meetings on the Plains.

It has been necessary in choosing assistants to go to other institutions for such help. I believe this policy to be one which will materially strengthen the Department, as it brings new ideas and new blood into the work. The experience gained in other schools cannot be used directly, because outside conditions differ from ours. But with the acquisition of an acquaintance with our conditions, the outside experience aids in placing or weighing local values. We advance in teaching efficiency and power by acquiring new and more advanced ideas rather than in a rehash of old ones.

The varied experience and information obtained through the work of the Department in the Experiment Station is thus put at the service of the teaching force. By this means much that is new and

interesting concerning the Agronomy of this very varied State is brought to the class room. Such practice increases interest and, it is hoped, better equips the student for meeting the agronomic problems of the State when he comes in contact with them later in his post-school experiences.

Respectfully submitted,

ALVIN KEYSER,
Professor of Agronomy.

REPORT OF THE DEPARTMENT OF ANIMAL HUSBANDRY.

To the President:

Instructional work in the Department of Animal Husbandry has been greatly modified during the past year. Standardization of the first two years of the agricultural course, with specialization, in Animal Husbandry during the Junior and Senior years, gave opportunity for the introduction of advanced work in livestock subjects. Specialized courses in animal nutrition, meat work, sheep farming, beef production, swine growing and horse rearing have been added, bringing the work up to the higest plane of collegiate education in animal husbandry.

Livestock, dairy, and poultry work have been consolidated in this department since the last annual report. The teaching work was carried during the school year 1909-1910 by two men. Another man was added this year. The addition of the dairy work, and increased attendance in the school of agriculture, necessiating the sectioning of classes, has made the first semester's work equal to that of last year; while the second semester's work will average six hours a week heavier for each man.

The department is this year holding weekly meetings in which the instructional work and other departmental work is discussed. While this is a new departure, the tendency of the meetings is towards a greater solidarity of the department and a strengthening of weak points in the instructional and departmental work.

The correspondence of the department has aggregated approximately 1,200 letters during the past year. The bulk of this correspondence has been in the nature of answers to inquiries concerning the handling of livestock and the sale of animals. With the addition of the dairy and poultry correspondence, the number of letters is greatly increasing.

Extension work has been done as follows:

Ten articles have been furnished for "News Notes."

Six institutes and one farmers' short course have been attended.

Judging has been done at four fairs, and superintendent's work done by two men at one fair.

Senior students have been furnished for judging at two fairs.

Station work, which is a very important part of departmental work, is detailed fully in the report to the Director. Two bulletins have been published during the year, and material for two others is on hand.

Respectfully submitted,

G. E. MORTON,
Professor of Animal Husbandry.

REPORT OF DEPARTMENT OF BOTANY AND FORESTRY.

To the President:

In both lines of work the schedule has been followed as outlined in the courses of study. In Botany each subject offered has been taught, while in Forestry only the work scheduled for the Junior year has been given. This is due in the latter case to the fact that this course is but two years old and that the technical subjects in Forestry begin with the Junior year.

The increased work of instruction, entailed by the teaching of Forestry, made it necessary for the Botanist to have help. Mr. M. Pesman, one of our graduates, was engaged for the ensuing year to assist in teaching. As this is only a temporary arrangement and as there will be additional teaching to do next year in Forestry it will be necessary to secure an assistant with more extended experience and training along the lines of work taught.

In all eleven classes have been instructed during the year, with a total enrollment of 92 four-year students.

Extension Work.—The correspondence during the year has been nearly double that of any preceding year, and consisted mainly of inquiries concerning weed eradication, tree planting, nature study and the naming of plants.

Three weeks were spent during the summer in teaching elementary agriculture and nature study at district institutes for teachers. In addition to this an outline for nature study in the rural schools has been prepared for publication by the State Department of Public Instruction.

In thus promoting the introduction and encouragement of agricultural instruction in our rural schools I believe we are doing a much needed work.

Farmers' institutes were attended at Fountain and Elbert during the summer.

An article for "News Notes" has been furnished monthly.

The equipment for the work in Botany and Forestry is fairly good, and while improvement in some lines is desired, everything asked for in this connection has been supplied as needed.

One thing which the Botanist greatly desires to be able to undertake in the future is the planning and establishing of a botanic garden on the college grounds. This could be made a most attractive feature of the campus, as well as a source of supply for materials in laboratory teaching, which must now be sought for at a distance often at the expenditure of considerable time and labor.

Respectfully submitted,
B. O. LONGYEAR,
Professor of Botany and Forestry.

REPORT OF THE DEPARTMENT OF CHEMISTRY.

To the President:

The work in the Department of Chemistry has been in strict conformance with the prescribed work as given in the college catalogue.

The number of students enrolled so far in text-book work is 109, in laboratory work, 43. The latter number will be greatly increased during the second semester. The veterinary students are using one text-book and the regular classes another. This difference is made because we believe it to be to the advantage of the students in the respective courses. The classes this year are so large that it has been necessary to divide them into sections, which, of course, increases the teaching hours. This is better however, for the students than to have them in larger classes, especially as we find ourselves almost forced to follow the recitation or catechetical method of teaching in which a class of 25 is almost too large. I will state that we have in years past tried the demonstrative, or lecture system, but it proved very unsatisfactory with students accustomed only to the method of recitations. I am fully convinced that our present method is the one best adapted to our conditions.

We have been compelled within the last few years to change the character of the work in the laboratory and to begin with elemen-

tary work in qualitative anaylsis instead of quantitative experimentation, in general chemistry, which course we followed for a number of years with very good results. I mention this because the adoption of quantitative instead of qualitative work for the purpose of instruction in general chemistry is now receiving attention from teachers and the writers of text-books. I adopted this method in our laboratory sixteen or seventeen years ago and followed it for eleven or twelve years, but the changes in the curricula of the various courses demanded by different departments has necessiated us to adopt the most feasible course under the circumstances.

The Chemical Department has no special course of its own. I do not believe that conditions justify us in attempting to establish one. The work of the department is consequently wholly general and supplemental to the courses established in other departments. These statements apply to instructional work and do not at all relate to research work pertaining to our Station duties which are not referred to in this report.

The force of the department has worked harmoniously and been a unit in trying to maintain a healthy spirit and a fair standard of work.

The influence of the work of the chemical section of the Experiment Station upon the work of the Chemical Department of the College has, in my opinion, been very beneficial. The relations of the two are not intimate, but it is well, perhaps, better that they are not. The station work is close enough to the college work to make it, the college work, real and serves as a constant incentive to raise the latter.

I regret to say that within the past few days, even since this report should have been in your hands, Prof. F. C. Alford, who has been with us for the past thirteen years, informs me that it is his desire to accept another position and wishes to be relieved from his present duties not later than the 10th of December. Professor Alford has been efficient and faithful in the discharge of his duties, he took one year's leave of absence to study in an eastern institution better to fit himself for his work. With this exception he has not been absent on account of sickness, or from other causes, for more than a very few days, less than one month, in all this time. His record in the class room and in the laboratory as an instructor and an analyst has been excellent. It is with great regret that I find it my duty to communicate this information to you. Through Professor Alford's resolution to enter upon another position the department and the Institution loses a faithful and efficient man who

always desired to advance the interests of the College and was in sympathy with the best interests of the students.

Respectfully submitted,

WM. P. HEADDEN,

Professor of Chemistry.

REPORT OF THE DEPARTMENT OF CIVIL AND IRRIGATION ENGINEERING.

To the President:

June 15th I was placed in charge of this department as Professor of Civil and Irrigation Engineering. I was notified that my new position would include the instructional part of the work, and that for the present the experimental side would be separate and under the supervision of Director Gillette.

Mr. Ralph Parshall was appointed Assistant Professor of Civil and Irrigation Engineering, and together we have pushed the work during the summer and fall. The problem which confronted us was a big one. True, we had a splendid new building, but there was nothing in it. After figuring the cost of the equipment necessary to give instruction in irrigation work and comparing this with the amount allowed in our budget, we found that in order to make any showing at all we must spend our money for material only. We got together, took off our coats, and went to work. The Janitor for this building was formerly a carpenter. Mr. Parshall and myself are what might be called "handy men," and together we fitted up the Cement Testing Laboratory, the Irrigation Laboratory, the Dark Rooms and the Class rooms. The Cement Laboratory contains an immersion tank, moist closet, bins for cement and aggregates, an instrument case, mixing tables and wall bench together with the necessary plumbing. As soon as our cement testing machine can be ordered we will have, together with the apparatus already on hand, an up-to-date laboratory for practical as well as instrumentional work in this branch.

In the Irrigation Laboratory we have so altered the large hydraulic tank that it is now suitable for pipe work, pump work and power work under all heads up to 400 feet. The long tank in the floor was lined up and water proofed by plastering out on the sides; angle irons were set so as to allow it to be divided by steel bulk heads and thus give an "elastic" tank as it were. A rating car has

been designed and constructed and is now ready for use and we have now the only perfect rating station in the West. We have installed a 15 H. P. motor which is connected with a long line shaft driving the pumps when installed. We have installed also an air compressor of about 80 cubic feet capacity for the purpose of producing the necessary pressure when working under high heads. This equipment puts us in a position where we can make practical pump tests, and as pumping for irrigation is bound to grow in importance, there will be demand for work along this line. The long floor tank gives us really an indoor irrigation ditch with known dimensions and under absolute control where the water may be allowed to run or be held stationary in a tank for measurement purposes. It gives us an opportunity to do all kinds of weir work and meter work which plays so important a part in the measurement of water. We have also resurrected and repaired a large set of scales and tanks for the more accurate measurement of smaller quantities of water.

You will notice that all this apparatus is of sufficient size for practical work, and not designed for theoretical experiments only, and it is our intention to throw the laboratory open for extension work so that people over the State may come here and find facilities for doing experimental work with irrigation apparatus, or send the apparatus here and have us do the work for them. Already we have had two calls, one from the Metal Flume & Culvert Company, of La Junta, and another from the McGinnis Metal Flume Company. In each case we have determined the co-efficient of roughness for their conduits, which was not before known for this particular kind of structure.

We have a donation of two pumps; one a rotary pump which won first prize at the Irrigation Congress Exhibit at Pueblo, the other a Blazer Patent Spiral Pump from the Humphrey's Manufacturing Company of Mansfield, Ohio. These were both secured in lieu of the tests to be made and a statement of the results to be sent to the manufacturer.

On the upper floors furniture has been placed in the library and seats in the class rooms so that we can now take care of the students in the department.

The above work has kept us busy during the summer and the Saturdays and odd hours during the fall.

During the summer Mr. Parshall and myself each spent two weeks on farmers' institute work, speaking in fourteen places on subjects related to irrigation.

At the opening of the school year we spent two weeks in the

mountains on the annual "Field Camp." This was a most successful camp, and the work done by the students the best and most accurate ever done by a "Field Camp" crowd from C. A. C.

All the work scheduled for students in this department is now taught.

Five articles for the "News Notes" have been contributed from this department.

I wish to thank the members of the Board and especially the members of the Executive Committee and yourself for the interest taken in our work and the help given us.

Respectfully submitted,

E. B. HOUSE,

Professor of Civil and Irrigation Engineering.

REPORT OF DEPARTMENT OF ENGLISH AND HISTORY.

To the President:

By Board action, June, 1910, the Department of History and Literature, Constitutional History and Irrigation Law, and English and Philosophy, were consolidated into the Department of English and History. In accordance with that change you will note that the work of the Winter and Spring terms of 1909-1910 shows only classes in the Department of English and Philosophy, while the work for the First Semester of 1910-1911 is the report for the new Department of English and History.

In the department there are at present the following teachers:

Dr. W. R. Thomas, Associate Professor of History and Law.

Virginia H. Corbett, Associate Professor of History and Literature.

J. B. Crabbe, Instructor in English (C. S. A.)

Zula M. Brockett, Instructor in English and Literature.

B. F. Coen, Professor of English.

The teaching force is the same under the new organization as it was under the old, and the different members of the new department are teaching about the same line of work as they were before. Owing to increased enrollment in the College and in the School of Agriculture, it was found necessary to secure an additional instructor in English.

It should be remembered that Miss Corbett, on account of her work as Adviser of Women, gives only half her time to the department.

Extension and Committee Work.—During the year Doctor Thomas has been a member of the Catalogue Committee. As such member, he wrote the article on "The Mission of the Agricultural College." He delivered the high school commencement addresses of Hotchkiss and Idaho Springs.

Mr. Crabbe has had charge of the athletics in the School of Agriculture, and he has helped Coach Cassiday with the College football team. He has also helped in the School of Agriculture literary society.

Miss Brockett's work has been wholly class instruction.

I have been a member, during the year, of the following committees:

Social Committee (Chairman.)
Executive Committee (Proctor for Freshman Class.)
Registration Committee.
Rural Education Committee.
Co-ordination Committee (Chairman.)
Catalogue Committee (Chairman.)
Student Correspondence Committee.

About one-third of my time has been taken up with these committees.

During the summer I went on an institute trip in the Arkansas Valley. I talked on "The College and The School of Agriculture." At the close of the institute trip, I visited the towns of Holly, Lamar and Las Animas on a campaign for students. Later, I visited Loveland, Berthoud, Longmont, Greeley, Fort Morgan, and Sterling for the same purpose. I wish to state that everywhere I went people were interested in the College. I could not wish for more courteous treatment than I received on these trips.

During the summer I also sent out letters and postals to this year's graduates of the Colorado high schools. For about two weeks I looked after the correspondence this line of work brought forth.

This fall, with the assistance of my senior class in Practical English, I got out a Campus Guide and Directory of the Instructional Force of the College.

In the main, the work done in the department has been satisfactory. Every effort has been put forth to increase efficiency. Departmental meetings have been held every two weeks or oftener. The co-operation of the other departments of the College has been sought in an endeavor to make students more capable in their use of English.

There are three things that I had hoped to do this year that time has not permitted. I wished as Proctor of the Freshmen class,

to confer monthly with every member of the class. I wished to have every bit of written work that came in, read and graded. I hoped that time might be found to go over this written work with the students, individually. The work will be more efficient when these things can be done.

Respectfully submitted,

B. F. COEN,

Professor of English and History.

REPORT OF DEPARTMENT OF MODERN LANGUAGES.

To the President:

In the Department of Modern Languages, a one-year course in German is offered. This work requires, as a prerequisite, two years of German grammar. The work done here consists of prose composition, conversation, with the daily reading of some standard German prose. The course is an alternative required in general science and domestic science and in electrical engineering.

Two years of French are given. The first year is necessarily devoted to grammar, reading and the memorizing of words and phrases. The second year's work is a continuation of that of the first, an important addition being the reading of technical and scientific articles from current French magazines and periodicals. The aim is to make the course as technical and practical as possible. The civil, mechanical and electrical engineering students, and the students in the general domestic science courses, are required to take either this work, or the course in German or that in Spanish.

A one-year course is offered in Spanish. The demand for a second year's work in the language is growing annually. For students planning work in the Southwest, or in our dependencies, Spanish is a practical necessity, and it might be well in the near future to make further provision for such students. Twenty-seven of the sixty-seven language students are taking Spanish.

The department has been strengthened this year by the introduction of a course in word analysis. This course was put in at the request of the Veterinary Department, and its aim is to co-operate with this department in that part of the veterinary work which has to do with the use and meaning of scientific words and phrases.

Respectfully submitted,

SARAH I. KETTLE,

Professor of Modern Languages.

REPORT OF THE DEPARTMENT OF FARM MECHANICS.

To the President:

During the months of May and June nearly all my time was taken up by the investigation of farm machinery conditions throughout the State. The results of this investigation formed the basis for the bulletin "The Life and Care of Farm Machinery."

I was granted a leave of absence by the College during the months of July and August. These two months were devoted to assisting Prof. H. M. Bainer in the writing of the bulletin "The Life and Care of Farm Machinery." Some time was also given to assisting in the construction of an experimental road upon the college grounds.

The work for the bulletin on "The Life and Care of Farm Machinery," and a small pamphlet telling of the success of the paraffine-lined cider cistern, which was built and tested by this department, is all the experimental work that has been done during the past year.

The cider cistern was built by the department and tested for one year. It proved to be so satisfactory that it was deemed advisable to publish the results in pamphlet form.

Many "News Note" articles have been furnished by the department during the past year.

Scarcely any extension work in the field has been done, except while I was out on investigational work for the bulletin on "The Life and Care of Farm Machinery."

The department is the recipient of a great many inquiries on all lines of farm machinery and farm motors. The answers to these inquiries, together with what correspondence is required to keep up our stock of loaned machinery, requires on an average about two hours a day the year round.

The department has secured some new machinery during the past year. Among the new machines loaned the department are three new model six-foot binders, a new Spalding tilling machine, new hay loader, an up-to-date side delivery hay rake, two new beet cultivators and a new style concrete mixer. The department has the written promise of a new style J. I. Case 15 H. P., traction engine and a Hart-Parr gasoline traction engine. This brings the farm machine equipment up to date.

A class room exhibition case has been purchased. It is now fitted up with model boilers, steam guages, injectors, etc., for farm motor work and with farm machine models and samples too numerous to mention. These models are all used for class room work. They are valuable in that they do away with the necessity of taking the classes from Agricultural hall to the farm machinery building for class room demonstrations. This means a great saving of time in class room work.

Respectfully submitted,
H. B. BONEBRIGHT,
Instructor in Charge.

REPORT OF THE DEPARTMENT OF HOME ECONOMICS.

To the President:

I submit herewith the annual report of the Department of Home Economics:

Since the retirement of Miss Mary F. Rausch, October 22d, on a leave of absence, the writer has served as Acting Head of the Department.

As a matter of interest a statement of comparative enrollment is given:

	Fall 1909.	Fall 1910.
Freshman	7	25
Sophomore	9	8
Junior	5	12
Senior	3	6
Special	18	11
	42	62

School of Agriculture:	Fall 1909.	Fall 1910.
First Year	54	61
Second Year	10	24
	64	85

The student body, in so far, at least, as it is represented in the Home Economics Department, shows unusual maturity. Ten students

among those newly registered have presented credits for advanced standing from normal schools and colleges.

Beyond the statement that during the last school year all courses scheduled in the catalogue were taught, there is little to add advantageously. The readjustment of college courses on the semester basis has been accompanied by some rearrangement of the departmental instruction. This has made possible a more logical presentation of work. Again we can now require of specials, as well as of students regularly registered by classes, the basic work in science. This appreciably strengthens class work.

A plan which the departmental faculty hopes to carry into effect for the next school year is that of compiling laboratory manuals for the courses of that character, these to be furnished to the students at cost price. At present a manual issued by he University of Chicago, is used with a considerable degree of satisfaction and success. The needs of the average student in this college, are, however, quite distinct from those of the average student of the University of Chicago. Such laboratory guides as we have in mind shall take into consideration this difference. If this plan is carried out, I believe it will be of very special benefit; first, in that we shall not put into mimeographed or printed form laboratory directions not most carefully planned; again, in that it shall give to the student at once the face value of well developed laboraory plans.

For the School of Agriculture classes the above plan cannot be so effectively used. The essential difference between the College and School of Agriculture courses is that in the latter the work contains less work of experimental nature, is in larger part the doing, according to direction, without being so able to go into the "why." In the School of Agriculture classes we cannot assume basic preparation in the sciences.

Owing to the overflow condition of the department during the early fall of this year, the cooking classes of the School of Agriculture have been given but half of the time scheduled. Six of the courses offered have been taught in class rooms in other buildings. After the Thanksgiving recess when we shall be housed in the new Hall of Household Arts, all work will be fully cared for.

Assistants.—Three Senior college students are each giving six hours a week as teaching assistants in First Year School of Agriculture classes, under the direction of an instructor. This teaching will continue through the winter. Miss Edna Neff, formerly in charge of the Domestic Science work at the State Home for Dependent Children, Denver, has been engaged to give temporary assistance, for two months, beginning October 7th.

Extension Work.—Aside from the work of giving instruction in the class room a considerable amount of time has been given to extension work.

During the seven weeks beginning January 17, 1910, Miss Rausch visited thirty-one high schools throughout the State. This visitation we believe to be largely responsible for the increased attendance of young women. A housekeepers' conference extending throughout the week January 3-8, was conducted at the College. The enrollment for the week was two hundred and seven.

During the past summer Miss Rausch taught thirty-five sessions in Norman Institutes, having a total enrollment of 804. and I taught in twenty-five sessions having a total enrollment of 355.

It remains to express appreciation of the interest and courtesies extended by members and officers of the State Board of Agriculture, and by members of the Faculty.

Respectfully submitted,
INGA M. K. ALLISON,
Acting Professor of Home Economics.

REPORT OF THE DEPARTMENT OF HORTICULTURE.

To the President:

The change in the course of study of last year has lightened the teaching work of this department quite materially owing to the fact that the plant physiology and plant breeding which were previously taught in this department are now studies common to the agricultural group and are taught by Professor Longyear, of the Department of Botany and Forestry, and Professor Keyser, of the Department of Agronomy, respectively. Last year four students graduated from the horticultural course. At present we have four Seniors and five Juniors taking horticulture. No horticulture is taught until the second semester of the Sophomore year which is common to all the agricultural group. The School of Agriculture has materially added to the teaching work of the department, as the number, one hundred and five students, requires this work to be divided into four sections.

The work in this department is divided between the teaching work of the department, office or executive work, extension work, including institutes and correspondence, and the station work. The station work occupies the larger part of my time. It is difficult to estimate the exact amount of time devoted to these different branches

of the work as they overlap in such a way that few days are devoted exclusively to any one kind of work. During the year practically 1,000 letters have been written in answer to correspondence concerning horticultural problems in this State. More than two months have been devoted to institute work in various parts of the State. Several trips have also been made in the State in the interests of the experiment station. Occasional articles have been written for "News Notes."

We believe that the course of study as adopted last spring is one that will make the student proficient in the particular lines that they take up. The only criticism or suggestion from the horticultural standpoint is that our students need more laboratory and practical work in horticulture to enable them to fill the many important positions that are constantly opening up in this line. We recommend that sudents spend their summer vacation in practical work. This is particularly desirable for the last two years of the course.

Respectfully submitted,

E. R. BENNETT,

Professor of Horticulture.

REPORT OF THE LIBRARIAN.

To the President:

Several changes have been made in the library during the summer which have added both to the appearance and to the comfort of the building.

A stack has been placed in the south basement, and this has made it possible to remove all books from the floor and to place them on shelves. In the old reading room a skylight has been built into the roof. This saves light bills, and, what is far more important, eyesight. Now that this room is cheerful the students are using it more. It is furnished with small tables. The students do better work in small groups, and the question of discipline is practically eliminated The room back of the reference room has had its stack removed to the basement. It has been papered and painted. We are now using it for a periodical reading room, and for student exchanges. The delivery room has had two book cases placed elsewhere, and is lighter and airier.

Documents.—Thirty-six hours have been given to the documents in the basement since September first. Checking the departmental libraries has lessened the time that ordinarily would be given to this work. As the regular library work must always be done, and as the

student public must be waited on, the document work will suffer until we have a special document clerk.

Decoration.—We have had a poster sale this fall, and from the proceeds have bought a picture for the periodical room. Mr. Pierce of the Mechanical Department is having one of the students make us a frame as a class exercise

Statistics.—1,171 books have been added to the library by accession from Nov. 1st, 1909 to Nov. 1st, 1910. This does not necessarily include cataloguing. New record work moves slowly, partly on account of back work, partly because the demands of the counter are increasing, and largely because we are a small library with a limited force.

We have been open 179 nights, or five nights a week during the college year, and have had an attendance of 2,084 people, or 11.6 persons each night. We have been open 219 days when students were here, and have lent 2,962 books. As a matter of fact, the library is open every day excepting Sundays and legal holidays whether the students are here or not.

Our statistics mean very little. As one person, only, is on duty at night, it is possible for students to come and go without being counted. The library is used more or less by the people of the town, and especially by club women. This work is all reference, as is the bulk of the college reading. Of this it is impossible to keep a record.

Five articles have been written for "News Notes" this year.

Future Work.—During the coming year we hope to add materially to the agricultural publications of the various state boards of agriculture. Miss Dilts has already made a good beginning here. We wish to do more with the public documents of Colorado. There are many gaps in the long sets both in the general and departmental libraries. The Government has offered to give us some help in this matter after January 1st. The library also intends to buy for these gaps, rather than new books the remainder of the year.

Eventually we ought to work up little loan libraries for the farmer, and charge a small fee. This can be done from our agricultural duplicates. Our binder now is working on a cheap pamphlet binding.

Respectfully submitted,

CHARLOTTE A. BAKER,

Librarian.

REPORT OF THE DEPARTMENT OF MATHEMATICS.

To the President:

Last winter term I taught four classes daily, comprising fifty-one students, twenty hours a week.

Miss Frink and Miss Cash each withdrew January 1, 1910. The former taught four classes daily through December 1909, comprising 120 students; the latter, four classes daily, comprising 63 students.

Last spring term I taught five classes daily, comprising 41 students, twenty-five hours a week.

For the present semester I have four classes; one comprising 18 in Calculus, and three in Trigonometry and College Algebra, comprising 31, 28 and 7 respectively, in all twenty hours a week.

Miss Durward has five classes daily in the School of Agriculture, comprising 16 in Algebra and 37, 27 and 17 respectively in Arithmetic. She also has one class three times a week in the College, in Solid Geometry, a class of three. Miss Durward is doing twenty-eight hours of teaching a week.

Miss Miriam Miller and Miss Nida Deal each have a class in Algebra in the School of Agriculture. These classes meet five times a week and comprise 18 and 28 students respectively.

With my present schedule I find it almost impossible to assist in College Extension or other lines of work. During last summer I went with Dr. Glover on an institute trip, explaining the work of the College by public addresses and personal work in nine different localities.

The Department of Athletics continues to demand much of my time. The condition this year is much improved over last, both as to finances and general interest. In my judgment the scheme for season tickets is responsible for the better condition.

I have been working with the leaders of the student body in an effort to organize an association among the upper classmen which shall tone up our so-called student life and act as a check in many ways upon the differences growing out of our complex system. We have had two meetings to this end and another meeting appointed at which a committee on organization is to report. I can only say that the present is assuring of good fruits.

In conjunction with Miss Durward, I am interested in the project of a practical course in Arithmetic for the first year of the Colorado

School of Agriculture. Besides getting a part of the work typewritten we have been able to do but little, due to the pressure of the schedule.

Respectfully submitted,

S. L. MACDONALD,

Professor of Mathematics.

REPORT OF THE DEPARTMENT OF MECHANICAL ENGINEERING.

To the President:

The results attained in the Department of Mechanical Engineering throughout the year have, in the main, been gratifying. The change from the term to the semester plan has caused some slight confusion, but not nearly so much as was anticipated. Some changes in the way of improvement have been made in the course of study, but the underlying principles of the course cannot be departed from to any great extent, except as we may, from time to time, modernize methods of teaching in the class room and laboratories and adopt improved text-books and apparatus.

During the past year, we have taught in the different classes, shops and laboratories a total of 592 students, counting each student once in each class he attended. This apparently large number counts also the students of the School of Agriculture, who receive instruction in the shops.

The increase in the number of students taking shop work has necessitated the addition of new equipment, and nine woodworking benches, each with a complete set of carpenter's tools, have been put in use in the wood room.

In the forge room sixteen forges have been added. These are of the very latest design, and they are completely fitted out with tongs, hammers and other necessary tools.

A number of class room models have been added to our equipment during the year. Some have been made in the shops, and some have been presented to us by generous and interested manufacturers. These models are of great value in showing the application of the principles taught in the class room.

The principal directions along which growth is desirable are in the machine room and the mechanical engineering laboratory. In the machine room work can be done which can be carried to a certain

point where it has to stop for want of the necessary tools and machinery.

The great advance of the department must now lie along the lines of the mechanical engineering laboratory work, and if the department is to live up to its name it must receive consideration for its engineering laboratory.

Respectfully submitted.

J. W. LAWRENCE,

Professor of Mechanical Engineering.

REPORT OF THE DEPARTMENT OF MILITARY SCIENCE AND TACTICS.

To the President:

I have the honor to report an increased attendance in the Military Department for the year 1910-1911, especially in the School of Agriculture. The discipline has also improved and the work has shown a creditable gain over last year in both branches. The band is making splendid progress and should receive all possible encouragement. The Department is hampered by lack of armory facilities and some provision must be made for indoor drill and gallery practice; three hundred cadets cannot be given proper instruction during inclement weather in the quarters alloted. The entire basement of the new part of the main building would only give the cadets the same floor space alloted to one company (fifty men) of the National Guard. I earnestly recommend that all of said basement be assigned to the Cadet Battalion for armory and drill hall.

I believe that the better discipline, morale, college spirit and efficiency in my department is due to the small allowances granted to Cadet Assistants by the Board and to the cordial support given me by yourself and Faculty.

Respectfully submitted.

H. D. HUMPHREY,

Captain, U. S. Army, Commandant.

REPORT OF DEPARTMENT OF PHYSICS AND ELECTRICAL ENGINEERING.

To the President:

All the work in college Physics for the year ending June last, was carried by Mr. Person, and the School of Agriculture work by Mr. Bonebright, Mr. Person's work was unusually heavy. The teaching of electrical engineering was done by Mr. Bessey and myself. All the work of the department has been of high grade and we have endeavored to improve wherever possible.

Considerable apparatus was added to the equipment for the electrical engineering laboratory, so that we are much better perpared to teach the subjects than at the beginning of the year.

In the sad death of Mr. Bessey we have lost a very valuable assistant and the College an earnest, capable, and loyal teacher.

Early in the spring the department moved into the building formerly occupied by the Civil and Irrigation Department. This gave us much needed room for office, class rooms and laboratories. Funds were provied for repairing the building and I spent all the summer vacation looking after this work and the moving of the dynamo laboratory from the mechanical building to the basement of the electrical engineering building. We are now well settled in the new building and while there are many needs, still, we are comfortable.

Last June we graduated the first class, a class of six from the Electrical Engineering Department.

The showing made by the return of students this fall was especially good. We have a Senior class of eleven, a Junior class of nine, all members of both classes returning; a Sophomore class of four, this being twice the number in the Freshman class the year before; and a Freshman class of four. This gives us an enrollment of twenty-eight in electrical engineering work.

The work is progressing nicely. Mr. Person has as before all the College Physics. Miss Elwell has been added to the department to take the School of Agriculture Physics. The work in Electrical Engineering is handled by myself and Mr. Staudt.

The electrical supply and repair work has been going along as usual. Since last December we have put in underground power, light, and telephone cables to the Civil and Irrigation Building and to Guggenheim Hall; installed transformers for the Civil and Irrigation Enginering and the Mechanical Engineering Departments; we have done all the electrical repair work and much new work about

the campus. Student labor has been used entirely for this work. Such work is of great benefit to the electrical engineering students, both financially and as a source of education and experience.

Respectfully submitted,

F. A. DE LAY,

Professor of Physics and Electrical Engineering.

REPORT OF THE DEPARTMENT OF PHYSICAL TRAINING

To the President:

My work began September 1st. It has been of a supervisory order, two departments (a) that of the boys, (b) that of young women.

The boys' department has been under my immediate supervision. There have been two branches of athletics participated in thus far, viz., football and track. Taking these up in order: Football, because it is the leading college sport, is given more attention than the latter. There have been on the average fifty men in uniform each night since College opened. A high degree of interest has been manifested by the boys. While the season has not been a success from some standpoints, from others it has been entirely satisfactory. The spirit has been good and the boys have worked faithfully, thus arguing well for the future of athletics along this line. In track there have been on the average, ten men out each night preparing for the first annual cross country run, which is being planned for the early part of December, thus making a combined number of from sixty to seventy men out for athletics each night.

We hope to hold an indoor and one outdoor inter-class track meet during the year. We are also planning for basketball, both for the young men and young women during the winter months. Plans are also being made for baseball in the spring. It is the aim of the Physical Director to get out as many men for the various classes of athletics as is possible, thus to meet the cry that college athletics is specified for the few rather than the whole student body. Therefore, it will be the aim of the department to have every man in College out for some branch of athletics during the year.

Respectfully submitted,

GEO. M. CASSIDY,

Director of Physical Training.

To the President:

Progress is manifest throughout the classes in the Department of Physical Education for Women. There are one hundred and twenty-nine pupils taking regular gymnasium work, which is the largest number of students taking physical training at any one time during the period which I have had the supervision of this Department. There is one division of College students and three of the School of Agriculture. Each division has regular class work twice a week, and there are teams of Volley Ball and Basketball which meet for regular practice at stated times during the week, outside of the regular class periods.

From the standpoint of discipline, the work has been easier this year than at any time during the two previous years. The attendance in each class, so far, has been perfect, and a spirit of co-operation and a growing interest is noticeable throughout. Many of the students who have been under my direction during the entire period of my work in this Department have come to me voluntarily and spoken of the benefit and also of the pleasure they have received in the Gymnasium. Some have been benefited from the standpoint of health—others have learned how to accomplish ordinary duties with a minimum expenditure of energy, and have come to see the real value and expendiency of systematic and regular physical exercise. Such sentiment among the old students has undoubtedly been advantageous to the new students, and the seeds they have sown this year have, as it were, fallen "into good ground," with the gratifying result that harmony and a spirit for work is manifest from every quarter It has taken, seemingly, a long time to gain this desired result.

One new feature has been added to the Department this year, that of requiring each student to take a physical examination This brings the Directress in personal contact with each girl who is required to take Gymnasium early in the year, and acquaints her with the deficiencies of those composing her classes so that she is better able to direct the exercises that they may always be a benefit. There have been fewer certificates of excuse brought to me this year as one of the immediate results of this new feature of my work. Also, with this personal contact with the members of my classes, I have found not a few who need corrective Gymnastics, and these receive private instruction each week. The necessary equipment for the taking of these physical examinations was barrowed from the Y. M. C. A., and I would recommend that equipment for this part of the work be added to the Department for next year.

I would suggest that, if possible, provision be made so that next year the College classes be arranged in Freshman, Sophomore and

Junior divisions, in order to make the work more progressive and therefore more interesting to each class. Also that this same provision be made for the first and second year students in the School of Agriculture.

Since work in the Department of Physical Education is required of each student attending College, I would recommend that Physical Training be given a place in the class schedule for next year, equally with any other required work of the College.

Respectfully submitted

C. AGNES UPSON,

Directress of Physical Education for Women.

REPORT OF THE REGISTRAR.

To the President:

The card system of registration and recording is being developed and improved, and the transcribing of the former record books to cards is progressing as rapidly as possible, this work being done as opportunity presents itself in connection with the other work of the office.

The record of daily attendance is kept in this office by means of a card system, a student's full record of absences being listed on one single card, thus enabling us to ascertain at a glance whether there is a lack of application or not.

A most thorough examination of the systems used in many of the largest and best institutions has been made during the year, and much valuable assistance has been received, and we shall be enabled to improve our own methods very materially.

I find in all institutions a striving for improvement in methods of registration and recording. Most methods seem to be too slow and cumbersome, and constant effort is being made to simplify.

Respectfully submitted,

J. W. LAWRENCE,

Registrar.

REPORT OF DEPARTMENT OF VETERINARY SCIENCE.

To the President:

Experiment Station.—A separate report has been made to the Director of the Experiment Station, of work done by the two Veterinarians on the Station staff.

Extension Work.—A large correspondence with farmers, stockmen, veterinary associations, etc. This work is attended to largely by the head of the department and D. B. F. Kaupp.

We also have the honor of being collaborators on the "American Veterinary Review," and regular contributions for the "American Journal of Veterinary Medicine." The head of this division is editor of the Veterinary Department of the "Ranch and Range," and, contributor to farm and livestock papers and in this work is ably assisted by the four veterinarians on the staff.

Dr. B. F. Kaupp took an active part in the deliberations of the Missouri Valley Veterinary Medical Association last February, in Omaha, and was honored by being elected President of the Association. Dr. Kaupp and the head of this division were privileged to attend the annual meeting of the American Veterinary Medical Association which convened in San Francisco last September, and the latter was honored by being elected its President.

We have furnished twenty-five articles for "News Notes," as follows: Dr. H. E. Kingman, 4; Dr. I E. Newsom, 4; Dr. C. L. Barnes, 5; Dr. B. F. Kaupp, 6; and Dr. G. H. Glover, 6.

We have attended eighteen Farmers' Institutes, as follows: Dr. H. E. Kingman, 1; Dr. I. E. Newsom, 2; Dr. C. L. Barnes, 5; Dr. B. F. Kaupp, 4; and Dr. G. H. Glover, 11.

College Work.—The object of the Veterinary College is well defined by the legislature of the State of New York, "To conduct investigations as to the nature, prevention and cure of all diseases of animals, including such as are communicable to man and such as cause epizotics among livestock; to investigate the economical questions which will contribute to the more profitable breeding, rearing and utilization of animals; to produce reliable standard preparations of toxins, antitoxins, and other products to be used in the diagnosis, prevention and cure of diseases and in the conducting of sanitary work by approved modern methods; and to give instruction in the normal structure and function of the animal body, in the pathology, prevention and treatment of animal diseases, and in all matters pertaining to sanitary science as applied to livestock and correlatively

to the human family." The motto of the Veterinary Department of the Colorado Agricultural College is "quality and not quantity," and the object is to give a thorough scientific training to a few men each year, to go out from this institution as guardians of the animal wealth and the public health.

Faculty.—Eighteen members of the Faculty teach in the Veterinary Department, of whom five are veterinarians. One veterinarian teaches in the School of Agriculture, and another in the College of Agriculture, Seniors and Juniors of the agricultural course. Still another teaches bacteriology to students of the Domestic Science and Agricultural courses. The head of this department is City Food Inspector of Fort Collins, but receives nothing for these services. The entire amount paid by the city for this work goes to Dr. H. E. Kingman, who does most of the work and from this source receives more than half of his salary. The U. S. Department of Agriculture requires that every class "A" Veterinary College employ five veterinarians on the teaching staff, and it is fortunate that we are thus able to perfect an arrangement with the city of Fort Collins whereby the College is saved half the salary of one man and the city is enabled to secure the services of two men at approximately half the salary of one.

Clinic.—When the Veterinary Department first assumed the proportions of a Veterinary College, it was argued by those who spoke inadvisedly, that the location of such a school in a small city was a mistake because a sufficient amount of clinical material could not be provided. All the Veterinarians on the staff have made a special effort in this direction, reaching out as far as one hundred miles for clinical material. We have worked day and night to bring in cases for the benefit of students and to give cases in the hospital the best possible care. I am pleased to report that we now have a clinic, in number and variety of cases equal to any veterinary college in the land. We have treated over a thousand cases a year. It is our wish now to systematize the teaching of practical medicine and surgery by dividing it into the distinct lines of consulting, medical, surgical, small animal and ambulatory clinics, with a member of the staff in charge of each line of the work.

Pathological Museum.—We appreciate the new offices given us in the Civil and Irrigation Engineering Building and for the large commodious room so well adapted for our pathological museum. We have in this museum over 500 specimens representing as many different diseases and parasites of our domestic animals. These specimens are of inestimable value for class room and laboratory instruction.

Pathological Laboratory.—The Pathological laboratory under the direction of Dr. B. F. Kaupp, is gaining an enviable reputation in

laboratory diagnosis. Five hundred and sixty-four cases have come to this laboratory for diagnosis in the last year. Of these 66 were for rabies, 89 for bloodcount, 24 urine analysis, 116 for cutanious and subcutanious inoculations, 24 for cancer, 14 swamp fever and 24 of these specimens were of human origin. There have been prepared 40,000 doses of black leg vaccine, 11,480 doses of antisuppuration vaccine and 2,000 doses of strangles vaccine.

We have reached a high degree of efficiency with a meagre expenditure of funds, and we are satisfied with the recognition given us in this State and throughout the land.

We can be of far more service to the State if more provision is made whereby we can go and help the farmer and stockman when he is losing a large number of animals from contagious diseases.

Respectfully submitted,

GEO. H. GLOVER,

Professor of Veterinary Science.

REPORT OF THE DEPARTMENT OF ZOOLOGY AND ENTOMOLOGY.

To the President:

Work of Instruction.—Most of the teaching, both in class room and laboratory, has been carried on during the past year by my associate, Prof. S. Arthur Johnson. During the last school year he conducted classes in Physiology, Zoology, and first-year Entomology. And delivered lectures to the Juniors and Seniors on Embryology and Evolution.

Miss Miriam A. Palmer taught a class in drawing from nature during a portion of the year.

Mr. L. C. Bragg has devoted much of his time to experiment station work, but has done a small amount of laboratory instruction for the classes in Zoology, Entomology and Embryology, and has had the care of the museum.

Extension Work.—Both Professor Johnson and the writer have given considerable time during the year to extension work in one form or another. Professor Johnson has been chairman of the Committee on Rural Education, which has required considerable of his time during the school year. He has also attended a number of farmers' institutes and teachers' institutes during the summer vacation. The writer delivered forty-eight addresses to popular and tech-

nical audiences, aside from the regular college work of instruction, during the year. Most of these were to the farmers and fruit growers of the State. Professor Jonhson and the writer have contributed a number of articles for College "News Notes" during the year

Museum.—No new material has been purchased for the museum during the year, but there have been a few contributions worthy of mention. Mr. Dana Q. McComb has placed in the museum a loan collection of interesting articles from the Philippine Islands, where Mr. McComb has been stationed several years in educational work.

The heirs of the late L. E. Burnett, who a few years ago acted as taxidermist for our museum, have placed in the College museum three cases containing 114 birds mounted by Mr. Burnett as a monument to his memory, with the understanding that the College will properly care for this collection and keep it as a unit.

During the year we have mounted and placed in the collection one elk calf donated by Mr. A. W. Scott of Fort Collins.

Dr. H. J. Livingston has presented to the department a collection of 100 histological mounts, nearly all of human tissues, which will be of much service in the laboratory work both in Zoology and human Physiology; and there have been several smaller contributions.

State Entomologist.—The Entomologist of the Agricultural College is designated by statute as State Entomologist, and upon him are imposed the duties which are incident to this office. So, during the past year, I have had charge of the horticultural inspection work in the counties of the State that have appointed inspectors. The number of these counties is twelve and the duties of this office have necessarily consumed much of my time. The First Annual Report of the State Entomologist, and Circular 1, giving information concerning the inspection, have been published during the year.

Our Graduates.—It is gratifying to be able to state, in closing, that all the graduates who have specialized in Entomology here are holding good positions, the call for prepared men for expert work in this line has been larger than we have been able to supply, and it has been greater during the past year than ever before.

Respectfully submitted,

C. P. GILLETTE.

Professor of Entomology and Zoology.

REPORT OF THE SCHOOL OF AGRICULTURE.

To the President:

After carefully considering the needs of the State and what the State Agricultural College might do for the boys and girls of the State, who have finished the eight grade work, but do not have access to high schools, or who, for any reason, do not care to enter the high school, the State Board of Agriculture decided to establish in connection with the Agricultural College, the Colorado School of Agriculture.

During the latter part of the summer of 1909, a vigorous campaign of advertising, through letters, circulars, and personal visits, was conducted and the school was formally opened with the present Principal in charge, Tuesday, October 5, 1909. The Board had said that it would be satisfied if there should be an enrollment the first year of from fifty to seventy-five, but to the delight of the Board and Faculty the enrollment far exceeded all expectations. In this connection it may be of interest to give a comparative statement of the registration for the year 1909 and up to November 15th of the present year.

	1909	1910
Those entering at opening of College in September	7	10
Those registering in School of Agriculture one day in advance of regular opening	111	108
Registration at close of first week	158	227

Total Registration.

1st Year Boys	131	
1st Year Girls	54	
2d Year Boys	18	
2d Year Girls	10	
Total		213

Enrollment to date this year:

1st Year Boys	123
1st Year Girls	63
2d and 3d Year Boys	53
2d and 3d Year Girls	24
Total	273

Your Principal considers this a remarkable record, since it took Nebraska School of Agriculture eleven years to secure 235, and the School of Agriculture of the University of Minnesota twenty-two years to secure 700. Our enrollment is not so high this year, however, as we had hoped on account of poor crops in the State.

Purpose of The School.—In the State of Colorado there are more than fifteen hundred districts in which there are no high schools. In these districts are found many people who are anxious for more training for their children than that afforded by the eighth grade. To these people there were, before the establishment of the School of Agriculture, practically no opportunities for further training than those offered by the high schools, and with the high school, as it now exists, they are not fully satisfied, because it does not give the kind of training they wish for their children. The high school has a tendency to educate away from rather than back to the farm. That the School of Agriculture satisfies a long felt want is shown by the enrollment for the first year. Forty-five of the sixty counties are represented this year.

Curriculum.—The curriculum has been arranged especially to train boys and girls for life in the open country. Thus far the work, as outlined, has seemed to cover the needs fairly well. If your Principal were to consider making any special changes in the curriculum as it now stands, they would be to give more time than three hours a week to Horticulture, as this field of work in the State of Colorado is a large one. The time now given to this subject does not seem to be commensurate with the needs of the field. The time is sufficient for text-book work but is not sufficient for the proper amount of laboratory work. Then, too, the time allotted for Dairying seems too short. As it now stands, one-half term of ten hours a week is given to Dairying. This field of work in the State of Colorado is a very promising one, and should be cultivated. The difficulty, however, in strengthening these two subjects in particular is the fact that the course is now as heavy as can be carried by the average student. Last year forge work and bench work were given ten hours a week each for one-half term. We found this to be too short, and this year each is given ten hours a week for one term, just doubling the work offered last year. To the bench work this year, in addition to the regular exercises offered, four things have been added, viz., rafter cutting, sill construction, the making of a miniature door frame and window frame, casing each complete inside and out. The time given to other subjects last year was found to be fairly satisfactory but none too long. It would be a pleasure to give a little more time to all subjects offered, but it is not possible to do so.

As the work now stands, a student may be admitted into the College by taking, in addition to the three years' work of the School of Agriculture, an additional or intermediate year of nine months. The work of the additional year has not yet been organized, not simply because we have not had a sufficient demand for it, but because we wish our experience to help us to decide what it ought to be. At present there is a growing feeling in the mind of your Principal that the additional year should be six months instead of nine, and the subjects therein should be largely elective. Those of the School of Agriculture who are looking forward to entering College have their minds pretty well made up already the courses in college they will wish to pursue. Your Principal believes that there should be a sufficient latitude in the matter of electives to enable the student to make his work during the fourth year an immediate preparation for the course he wishes to pursue in college. If the additional year should be made nine months instead of six months, he still feels that the fourth year should be made up largely of electives. The University of Nebraska has recently added a fourth year of six months to its School of Agriculture.

Method of Instruction.—The method of instruction followed has, as much as possible, been the text-book and laboratory method, rather than the lecture system. In some subjects it has been necessary, because of inadequate and unsatisfactory texts, to follow the lecture system more or less, but this has been made the exception rather than the rule, and if it were possible would be eliminated entirely. The lecture method is for advanced students, but not for students of secondary grade. Frequent quizzes or tests are given in all classes.

Discipline and General Supervision.—During the first part of last year the teachers sent in weekly reports of absences. These were soon found to be too far apart to bring the best results. Daily reports were then asked for and were checked up at first by the Registrar's office, but on account of other work of the office they were not always checked up promptly. This year the reports are sent daily to the Principal and are checked up by him in person. He is now enabled to know at once about the absences and to see after them promptly. Last year when they became too numerous the student was asked to come before the Executive Committee of the Faculty. This year each unexcused absence carries with it three demerits and zero, for a grade, and the number has been materially reduced. Last year what is known as the student self-governing plan was inaugurated. The students of the second year class were asked to elect six members from their body, the students of the first year class the same number from their body. The entire student body then elected a presiding officer from the second year class, thus giving a majority

to the maturer students. This body of its own accord took up and tried a number of offenders and recommended to the Principal what punishment they thought should be administered. A number of offences were dealt with that could not have been easily reached by the Principal. It should be understood that the control of the School is not in the hands of this governing board, but they simply help the Principal in dealing with anything that casts discredit on the School. The plan had its advantages and disadvantages. This year we are trying to overcome some of the disadvantages of the plan. On the whole it was a very satisfactory beginning. If, at any time, an offense should be too serious to be handled by this governing board and the Principal, it will be presented before the Executive Committee of the Faculty.

Respectfully submitted,

T. M. NETHERTON,

Principal.

REPORT OF THE DIRECTOR OF THE EXPERIMENT STATION.

To the President:

I have the honor to present the report of the Agricultural Experiment Station for the year just closing.

The financial statement and inventory of the Station will be found embodied in the financial report of the Secretary of the State Board of Agriculture.

This report has to do with three administrations. Prof. L. G. Carpenter was Director until June 1; you were Acting Director during the month of June, and the writer entered upon the duties of the office July 1st.

Organization.—The Station is organized for work under sectional heads as follows:

Chemistry	William P. Headden.
Irrigation Engineering	E. B. House, Acting.
Bacteriology	W. G. Sackett.
Horse Breeding	J. O. Williams.
Entomology	C. P. Gillette.
Horticulture	E. R. Bennett.
Agronomy	Alvin Keyser.
Animal Husbandry	G. E. Morton.
Veterinary Science	Geo. H. Glover.
Botany	B. O. Longyear.

Associated with the Agronomist is Mr. P. K. Blinn, as Alfalfa Specialist; associated with the Horticulturist is Mr. C. L. Fitch, Potato Specialist; and associated with the Animal Husbandman is Mr. W. E. Vaplon, Poultry Specialist. Then, upon the Western Slope we have two field men in horticulture, Mr. George P. Weldon, devoting his entire time to the study of insect problems, and Mr. R. S. Herrick, giving his time to the study of plant diseases and orchard management. On the plains, in the dry farming section, we have Mr. J. E. Payne, as a field man, studying dry farming methods, and Mr. J. W. Adams, in charge of the dry farming station at Cheyenne Wells.

Mention should also be made of labors performed by men detailed from the U. S. Department of Agriculture, at Washington. Early in July co-operative work in dairying was taken up with the Bureau of Animal Industry. Since that time Mr. R. R. Welch, Special field agent of the Bureau, has had his office with the Experiment Station and has been spending his time almost entirely in the field doing what he could to instruct the farmers in better methods of feeding and caring for their stock and handling their dairy products, and the best methods to pursue in building up better and more profitable dairy herds. Mr. Welch's only expense to the Station has been for office and office supplies.

The Office of Public Roads, of the Department of Agriculture, also co-operated very generously with the Experiment Station the past summer by sending one of its good roads experts, Mr. J. H. Dodge, with an engineer, Mr. W. R. Crecelius, to direct the construction of a piece of experimental road with money made available for that purpose by one of the State appropriations passed by the Sixteenth General Assembly.

The object in putting in this piece of road, which lies partly upon the College grounds and partly upon Laurel Street, adjacent to the College campus, was to demonstrate what could be done in the making of a first-class road with surfacing materials that are close at hand. A bulletin is in preparation giving full information as to manner of construction, cost, and material used in the building of this road. I believe the State Board of Agriculture should express to the Bureau of Animal Industry, and to the Office of Public Roads, their appreciation of the important services they have rendered the Experiment Station through their co-operation in our work.

Of the above Station workers, most of the heads of sections devote some time in instructional work in the Agricultural College, and a few have so much teaching there is very little time left for their experiment station projects. The specialists and field men devote their entire time to experiment station and extension work. The fact is that

a large part of the work of the field that has gone under the name of experiment station work is really extension or demonstration work and probably will be so classified in the future and placed in charge of the Superintendent of extension work.

Our Funds and How They May Be Spent.—The Experiment Station funds are from two sources, the general Government and the State, but they really are in three classes.

The Adams Fund.—Which gave us $13,000 the past year, but which has now reached the annual allowance of $15,000 a year, is very much restricted in its application and can only be used for scientific investigations of a rather high order. The ordinary "experiments," so-called, of the field, the orchard, or the feed yard, cannot be carried on under this fund, nor can any office expenses or expenses of publishing the results of experiments be charged to it. This fund calls for high priced men of ability in technical lines of work, and quick results can seldom be expected.

The Hatch Fund is a little more elastic and may be used for definite and well planned investigations which have for their object the discovery of new facts, or the testing of old laws under new or untried conditions and it can also be used for office expenses and the publication of bulletins that are the result of experiments under either the Adams or Hatch Funds, or any other fund the work under which is of Adams or Hatch grade. This fund also contributes $15,000 a year for our work.

State Special Appropriations.—The appropriations made by the Sixteenth General Assembly for the support of experiment station work during the biennial period just closing, were as follows:

Horticultural Investigations	$ 10,000
Potato Investigation	10,000
Animal Industry	10,000
Co-operative Horse Experiment	5,000
Poultry Investigations	5,000
Grains and Grasses	5,000
Farm Machinery and Roads	5,000
Cheyenne Wells Station	2,000

These funds have been expended in the lines of work for which they were appropriated and the results of the work have been, or are about to be sent out to the farmers in the form of bulletins and circulars or in the College "News Notes." Summaries of the different lines of investigation will be found in the reports here presented by the men who carried on the work.

The different lines of experimental work that have been carried on during the past year on all funds will be found in the reports of the different sections that follow.

Future Needs.—Colorado is young as an agricultural State. Her agricultural lands in the main are very fertile but the conditions of soil, climate and moisture are hardly the same for any two counties in the State. We are growing crops in all altitudes between 3,400 feet in the valleys of the Arkansas and the Platte, and 7,000 to 9,000 feet in the mountainous districts. The annual precipitation in the different agricultural sections ranges between about 7 inches and 18 inches. In the eastern portion where the precipitation is greatest, it is possible, under the most thorough farming methods, to grow certain crops with a degree of success, while other crops which grow luxuriantly in irrigated sections cannot be grown there at all. In the same county may be found, in some sections, flourishing peach orchards and the eternal snows upon the mountain peaks. And then we have an area nearly equal to all the New England states with New York thrown in. When we add to all this the specialized condition of our agriculture, one locality noted for its alfalfa and sheep, another for its sugar beets, another for potatoes, another for grain, and another for its peaches and its apples and still another for its pasture and meadow lands and its fine live stock, it can readily be seen that the agricultural problems to be solved for the benefit of the farming classes are many and important and extremely varied. There is also a class of problems associated with the application of water to land for the purpose of growing crops that the eastern farmer knows nothing about. If there is any state where liberal appropriations are needed for experimental work for the benefit of the farmer, I am sure Colorado should be placed in that class.

Publications.—The bulletins and circulars published by the Experiment Station during the past year are as follows:

Regular Bulletins.

No.	Title	Edition.	Pages.
153	Agricultural Products Shipped into Colorado in 1909	20,000	24
154	Alfalfa Studies—Third Progress Report	18,000	12
155	The Fixation of Nitrogen in Some Colorado Soils	5,000	48
156	Butter Making—Clean Milk and Commercial Starters	20,00	16
157	Arsenical Poisoning of Fruit Trees	5,000	56
158	A Bacterial Disease of Alfalfa	5,000	32
159	A New Alfalfa Disease—Stem Blight	20,000	16

160	Nitrates in the Soil	20,000	8
161	Cement and Concrete Fence Posts	20,000	20
162	Rabies	20,000	8
163	Farm Butter Making	20,000	16
164	Poultry Raising	20,000	16
165	Ration Experiments with Swine	20,000	24
166	Information Concerning the Colorado Carriage Horse Breeding Station	5,000	12
167	Life and Care of Farm Machinery in Colorado	20,000	20
168	Deterioration of Farmyard Manures	20,000	24
169	Some Insects Attacking the Peach	15,000	20
170	Thinning Winesap Apples—Winter and Frost Injury to Fruit Trees	15,000	20
171	Raspberry Growing	10,000	20
172	Garden Vegetables	20,000	20
173	Plains Orchard	10,000	8
174	Adobe Farm Buildings	10,000	8
175	Colorado Potatoes	20,000	80
176	Production and Degeneration of Potatoes	10,000	16

These 24 regular bulletins would make a volume of 540 pages and the total pages published is 7,786,000.

Press Bulletins.

No.	Title	Edition.	Pages.
50	Hints to Plains Settlers—The Home Garden	5,000	2
51	Hints to Plains Settlers—Sod Crops	5,000	2
52	Hints to Plains Settlers—The Cow as an Assistant	5,000	2
53	Hints to Plains Settlers—Windmill Irrigation.	5,000	2
54	Parafine-lined Vinegar Cistern	10,000	1

A total of 60,000 pages.

Correspondence Circulars.

No.	Title	Edition.	Pages.
7	Milo	5,000	16
8	Growing Potatoes in Colorado	5,000	24
9	Growing Broom Corn in Colorado	5,000	16

A total of 280,000 pages.

A grand total of 8,126,000 pages of printed matter published by the station during the fiscal year just closing.

Following are the reports from the various sections of the Experiment Station in which you will find brief summaries of the work that has been in progress during the year.

A careful reading of these reports will show that the Station force has been working upon problems of great importance to the various agricultural interests of the State. There are many others of as great importance that we should like to take up but are prevented from doing so from lack of funds to support the work.

Respectfully submitted,

C. P. GILLETTE,

Director.

REPORT OF AGRONOMY SECTION.

To the Director:

I transmit herewith my report of the Agronomy Section of the Experiment Station.

The following projects have been carried on under the Hatch fund:

Correlation of different Plant Characters with Intrinsic Values or Qualities.

Alfalfa Investigation.—The Correlation project was maintained by funds from the State Agronomy Appropriation. Hatch funds were used only to assist in paying a portion of the salary of the head of the Section.

This project is one which should run for a considerable period in order to eliminate, so far as possible, season differences. The work of the year, while largely preliminary, indicates possible lines of development. There is, for example, a seeming relation between certain habits of leaf growth in oats and barley and the adaptability of these crops to high altitudes.

The alfalfa investigation has, so far, been entirely supported by Hatch funds. Up to the present this project has been entirely the work of Mr. Blinn and has been carried on at Rocky Ford. Alfalfa is the foundation crop in Colorado agriculture and deserves even more attention than it has received in the past. We need to know more definitely how seed may be produced successfully and profitably; just what strains are adapted for different regions; what cultural methods give the greatest success; its effect on the soil when on the land for short and long periods; how the yield may be increased by usuable means; and many other things concerning the exact place of the crop in the different sections of the State.

The following projects are being carried on under State funds (The Agronomy Appropriation):

Project 1. Name, Wheat Improvement.
Project 2. Name, Feed Crop Improvement.
Project 3. Name, Rotation in Colorado.
Project 4. Name, Methods of Selection Breeding.
Project 5. Name, Farm Management.
Project 6. Name, Field Pea.
Project 7. Name, High Altitude Crops.
Project 8. Name, Preparation of New Land.
Project 9. Name, Correlation of Characters in Grain. (Partly supported by Hatch Fund.)

Project 10. Name, Plains Crops and Management.

Progress of Projects.—Project 1, Wheat Improvement—In this work three lines are being followed; 1st, prospective new strains are being introduced and thoroughly tried out; 2d, selection breeding is being carried on in the effort to improve the best adapted existing sorts; 3d, crosses are being made in the effort to combine desirable qualities of different strains. Special effort is being put forth to produce a high yielding wheat of good quality which will mature very much earlier than any of our present sorts. Progress has been made toward this end. There are now in our Wheat Breeding Nursery sorts which will ripen very much quicker than Turkey Red, our earliest winter wheat.

Project 2, Feed Crop Improvement.—Progress.

Project 3, Rotation in Colorado.—An investigation concerning the rotations best adapted for the various sections of the State, the effect of such rotations upon the soils and production. Rotations are carried on on farms. In addition information is gathered on the working of operative rotations. It would be possible to put out information at the present time.

Project 4, Methods in Selection Breeding.—Methods of Handling the selections in the various crops and regions of the State. Progress.

Project 5, Farm Management.—An investigation into the present systems of farm management in the State, and into methods of improvement.

Project 6, Field Pea.—Progress.

Project 7, High Altitude Crops.—Experiments and tests in the endeavor to find or produce profitable crops for our high altitudes, and to determine what crops are best adapted to the various regions, also what constitutes adaptability. Progress, and a Progess Bulletin now ready.

Project 8, *Preparation of New Land.*—Experiments, tests and information in methods of preparing and handling the different types of new lands in the different regions of the State. Considerable information is now on hand.

Project 9, *Correlation of Characters in Grain.*—Progress. Will require several years' data.

All projects are new.

During the past year the following publications were issued by the Department:

Press Bulletin 49, "Treatment of Seed Grain to Prevent Smut."

News Notes No. 135, "Growing Sugar Beets."

Correspondence Circular No. 7, "Milo."

Correspondence Circular No. 9, "Growing Broom Corn in Colorado."

Ready for publication:

High Altitude Crops—Progress Report.

Alfalfa in Colorado—Progress Bulletin.

Two classes of work are being carried by the Section. The first class aims to gather information, by experiment and otherwise, concerning the best crops and methods of handling the same, and put this information in the hands of the people as soon as possible, in order that it may be of immediate use and help in the farming operations of the State. Such work is of necessity, largely general and informational. But it is of large immediate value, and assists in raising the general level of our agriculture.

The second class of work which we are doing attempts the more exact and protracted investigation and study necessary for the solution of specific agronomic problems. This often means the continuation of a piece of work through a period of several years in order to eliminate unknown or uncontrollable factors. Except for the factor of time, these two classes of work are not necessarily antagonistic. Many of the specific projects, if successful, will point the way to a better agriculture. If negative results are obtained they will be equally valuable in showing what not to do.

The Plains projects were merged during the summer into one general project. This work has been quite productive. Mr. J. E. Payne, the Plains Field man, has prepared six reports, results of specific work done, which will be offered for publication.

Respectfully submitted,

ALVIN KEYSER,

Agronomist.

REPORT OF ALFALFA SPECIALIST.

To Alvin Keyser, Agronomist:

I herewith submit my annual report on the alfalfa breeding project in progress under my control. So far, this work has been supported by Hatch funds. There have been no new projects during the past year, and as my last annual report was published as a Progress Bulletin, that has covered the material really available for publication at the present time.

The past year's efforts have been directed along two lines of the alfalfa seed problem; First, observation, records and selections of seed from the alfalfa nursery have been made for the purpose of combining and improving the desirable traits that have been revealed. Second, observations and investigations have been carried on to find the factors that influence the setting of alfalfa seed, to determine the best methods for producing commercial quantities of seed.

Under the first line there are two important observations that have been made; first, that there seems to be a direct relation between the stooling habits of an alfalfa plant and its tendency to winter kill. The type of plant with the deep crowning habit that sends out root stalks beneath the surface of the soil, with the bud areas protected with earth, characterizes the non-winter killing strains, while the plant that has a small stool that throws out its shoots almost upright at, or very near the surface, has its bud areas exposed and is therefore easily winter killed.

These two types of plants are found to some extent in nearly all the common alfalfa, while the Arabian and non-hardy strains are of the latter described type. It does not follow that endurance to low winter temperatures is entirely due to the stooling habits, for there are other factors that may enter. But for Colorado conditions it seems very evident from the tests we have made that freedom from winter killing can be secured by selecting the proper stooling type of plants.

The second observation referred to was the marked disease resistant or frost resistant tendency of the Baltic alfalfa which was revealed by its freedom from the bacterial disease that seriously injured all the other varities that were growing under the same conditions in every particular. Professor Sackett, who has been investigating this disease, reports that it seems to be associated with frost injuries, and he also reports the Baltic variety as showing the resistant trait in a test that he has made at Gypsum, Colorado. The contrast in the test made at Rocky Ford this spring was very marked. It oc-

cured under field conditions in a five acre field sown in rows to test cultural methods for seed production. The field was seeded in 1909 to ten varieties, the seed being selected from the most promising plants in the 1907 nursery of sixty-four strains. The whole field was irrigated in the fall, and the space between the rows thoroughly cultivated in the spring, each variety receiving the same treatment in every respect. The field seemed to be very uniform until after a few sharp frosts the latter part of April, when the field began turning a light yellowish green, except a strip of fourteen rows through the center of the field, that was distinctly marked by dark green, normal colored foliage. On investigation it was found to be the rows that were sown to Baltic. The plants in these rows were nearly free from the bacterial disease, and the contrast became more marked each day as these rows continued to grow, while the balance of the field stopped growth for nearly ten days.

One half of each variety was cut for a hay test, about June 1st. The remainder of the field was allowed to go to seed. The advantage of the resistant trait of the Baltic variety is shown by the yield of hay per acre from the ten varieties computed on the yield of dry hay from an equal area cut from each variety, as follows:

Plat 1	Variety Developed from one plant found on Railroad Right-of-way. Yield per acre -----	4,126 pounds
Plat 2	Turkeystan. Yield Per Acre ----------	3,930 pounds
Plat 3	Utah Alfalfa. Yield Per Acre ----------	3,920 pounds
Plat 4	Dry Land Nebraska. Yield Per Acre --------	4,126 pounds
Plat 5	Argentine Alfalfa. Yield Per Acre --------	3,920 pounds
Plat 6	Baltic Alfalfa. Yield Per Acre----------	**5,702** pounds
Plat 7	Sand Lucern. Wash., Yield Per Acre ------	4,126 pounds
Plat 8	Peru Alfalfa. Yield Per Acre ----------	3,603 pounds
Plat 9	Arizona Alfalfa. Yield Per Acre ----------	3,870 pounds
Plat 10	Ecuador Alfalfa. Yield Per Acre --------	3,732 pounds

The contrast in growth of the second crop was not so pronounced. It was not cut for hay but left to go to seed. The Baltic was one of the best in point of leafy character and fine stems. The Baltic variety blooms almost a week earlier than most of the plats, and it also gives evidence of superior seed yielding traits, the results of which cannot be given at this time.

A new alfalfa breeding nursery comprising nearly eight miles of nursery row thinned to single plants, has been established the past season. The nursery is largely composed of individual plant selections from the Baltic and other very promising strains and varieties. Careful observations and records have been kept on any contrasts that have appeared, for future breeding investigations. One interest-

ing point was shown in the selections from the Baltic strain, of a decidedly less injury from the mildew that affected the leaves of nearly all the plats.

The Baltic alfalfa originated as a strain in South Dakota. A field over ten years old was discovered by Professor W. A. Wheeler near a little place called Baltic. The strain seemed to possess many desirable traits. This strain has gone out from the South Dakota Experiment Station as Number 167. The seed we have had come through the Department of Agriculture, and originally came from the Highmore Sub-Station, South Dakota.

There is hardly a doubt but that the Baltic strain originated from seed of the Grimm alfalfa, as the two strains are so near alike in many ways, but there is no direct way to trace its identity.

The cultural methods for seed production have not yielded the results hoped for on account of various adverse influences, namely, the test was made on new seeding. It was evident the field was over watered in the fall. While it had no other irrigation the field grew too rank a growth of hay for satisfactory yields of seed, as can be seen from the heavy yields of hay already reported. The bacterial disease and grasshoppers also modified results. The seed from the first crop on one-half of the field, and the second growth on the other half, is in the stack. An estimate is hardly worth while to report, but a bushel to a bushel and a half might be a close guess for the average.

The investigation has emphasized several points of great value.

1. That the cultivation of alfalfa in rows can conserve the moisture of one irrigation of the fall before to produce two heavy crops of hay, on soil of the character upon which the test was made.

2. That alfalfa in rows with irrigation furrows smoothed out can be irrigated with a minimum amount of water that is impossible where the alfalfa is sown broadcast and the field is flooded.

3. That the moisture control is one of the principal points in successful alfalfa seed production.

4. That alfalfa in rows will not lodge so bad as broadcast stands.

5. That weeds and grasshoppers can better be controlled by cultivation where the alfalfa is in rows, allowing intertillage.

6. That different varieties of alfalfa have different seed yielding traits.

There are many questions in relation to alfalfa seed setting that need solution, that will require more time and equipment to determine.

Respectfully submitted,

P. K. BLINN,
Alfalfa Specialist.

REPORT OF THE PLAINS SUB-STATION.

To Alvin Keyser, Agronomist:

The following is a report of the work at this station, for the season of 1910. The work has been carried on with a view to demonstrating general farming, combined with dairying and poultry raising. In connection with this there has been experimental work.

Because the land had not been properly treated during the previous season, it was impossible to follow strictly dry-farming methods for the present season's crop. This applies especially to the spring grain.

Orchard and Other Trees.—The orchard and shade trees have been pruned, thinned and cultivated so as to improve the health and general appearance very materially. On account of the freezes and hail the fruit crop practically failed. We had a few cherries (1½ gal.), a few gooseberries, and about a bushel of apples (Winesap, Missouri Pippin and Geniton varieties. There are some indications of blight in the orchard, but I think the difficulty lies mainly in a lack of moisture because the trees are too close together, and on account of insufficient pruning and cultivation in the past. The station should be provided with apparatus for spraying as the leaf rollers and kindred insects damaged the trees last spring. I have not seen any evidence of the codling moth in the apples produced.

Garden.—One acre of choice land was set aside for a family garden. In this we planted the following vegetables; potatoes, peas, beets, carrots, beans, onions (sets), radishes, turnips, lettuce, peanuts, tomatoes, cabbage, cantaloupes, water melons, cucumbers and preserve melons. From this garden we have raised all the vegetables used during the summer by the family and the hired help. In addition to this we sold from it $16.12 worth of vegetables.

Practically everything planted in the garden was a success except the water melons; they were destroyed by hail on the 15th of August. There were 1,500 melons on ¼ acre at that time and they would have ripened in a short time.

Experimental Plats, Stock Beets.—One acre was planted to stock beets. They came up nicely but were destroyed by hail on May 15th just as they were coming out of the ground. They were replanted twice, but failed to get a start owing to drouth. On July 7th I planted all but ¼ acre to Kafir using furrow opener attachment to corn planter. In spite of the long drouth this came up and made a good crop, clearly showing the value of the furrow-opener in dry seasons. The remain-

ing ¼ acre of beets made 400 pounds (estimated) of beets, or 1,600 pounds per acre.

Potatoes.—Besides the potatoes planted in the garden and used during the summer, we planted one acre for the station, with the following results:

Ohios, per acre, 1,304 lbs., Peach Blows, per acre, 1,[illegible] lbs., Pearls, per acre, 1,710 lbs., Rose Seedling, per acre, 1,700 lbs., Irish Cobblers, per acre, 1,440.

The potatoes were of very good quality. Considering the very dry season and the fact that the ground had no previous preparation (last season) I think that the results are encouraging. In addition to the above, I raised at the station 2 acres of potatoes for Professor Fitch. He will make the report on those.

Small Grain.—Seven acres were devoted to variety tests of spring grain. Four varieties of spring wheat planted as follows: ¼ acre of Durum wheat, ¼ acre of Bluestem; ¼ acre Velvet chaff; ¼ acre Fife. 1-10 acre of each of these was harvested with a cradle and an attempt made to thrash by hand to determine the yield. But it was found that mice had destroyed so much of some plats that a comparative yield could not be made in this way. It was thought we could get at a fair estimate only by observation. The values as estimated were from 4 to 7 bushels, in the following order: Durum, Velvet Chaff, Blue Stem, Fife.

Oats.—Three varieties of oats were sown, as follows: Kherson, Swedish Select, and Sixty Day oats. The same method of determining the yield was followed as in the case of wheat, and some difficulties were encountered. The Kherson and Sixty Day oats seemed to be identical. The Swedish Select came later and showed a better yield this season.

Estimated yield Kherson and Sixty Day oats, 10 bushels per acre. Swedish Select, 15 bushels per acre.

Barley.—Plats of common barley and Bald barley were sown. The common barley made good considering the season. The other variety was a failure. Our experience this year has shown that it is not practical to sow grains on plats without a small thrashing machine to thrash them with when they have been cut.

Stock Melons.—One acre was planted to stock melons. From this were gathered nine loads. They were fed to milk cows. Although the cows seemed to relish them very much we are unable to detect any increase in the flow of milk due to their use.

Corn.—Twelve acres were planted to eight varieties of corn. The drouth in the early part of the season was almost too much for it.

but the late rains brought it back so that we had an estimated yield of 6 to 12 bushels. Most of this was cut with a corn harvester and will be fed to the cows without husking.

Non-Saccharine Sorghums.—For variety test we planted 1-3 acres each of the following:

VARIETY	Fodder Yield Per Acre	Grain Yield Per Acre
Texas Seeded Ribbon Cane	2,000 Qual. good	000
Brown Knowliang	1,800 Qual. poor	585
White Durra	1,200 Qual. poor	339
Dwarf Milo	1,800 Qual. fairly good	745
Sudan Durra	900 Qual. poor	481
Black-hulled White Kafir	2,400 Qual. good	000
Dwarf Milo Kafir	2,400 Qual. good	670
Standard Milo	1,500 Qual. poor	627

The figures for fodder are in pounds (estimated.) These plats were thrashed by hand and the grain weighed.

Broom Corn.—Four varieties were planted in 1-3 acre plats. Owing to the drouth it was cut for feed, making about 3,000 pounds per acre fairly good fodder. This would have produced some good brush but it was believed to be more valuable as feed.

Beans.—Besides the beans planted in the garden, we planted ½ acre of cow-peas and Mexican beans in the field. The cow-peas made 5 bushels per acre. The Mexican beans were damaged by the hail and drouth more than the cow-peas, but made 3 bushels per acre.

Millet.—Four acres were sown to hog millet. It did not come up good; it made about ¼ ton per acre.

Summer Fallow.—About 4 acres were summer-fallowed and two acres of this were sown to Kharkof winter wheat. The wheat is looking fine now. About 4 acres were sown on ground that raised crop this season. Its appearance is not nearly so promising.

Sod Crops.—During the spring and summer thirty-two acres of new land were broken out and about twenty acres of this were planted in Kafir and Milo. Two plantings were made. The earlier produced a good crop of fodder and a fair yield of grain; it has not been thrashed. I estimate that it will yield 2,000 pounds of fodder and 500 pounds of grain per acre. The late planting did not produce grain but made about 1,200 pounds per acre of first-class fodder.

The Dairy.—On March 1st we had 18 head of cattle, as follows:

15 head of cows and heifers.

2 calves.
1 grade Red Polled bull.

The cows were selected from a rough herd. We began keeping a record of feed and cash receipts. Four of these cows were giving milk of March 1st. Eight more were fresh during the summer. On June 1st I began keeping individual records by use of scales and Babcock test. In October I sold five of the less promising ones. It is my plan to purchase as soon as possible at least one good Holstein cow and a Holstein bull. In this way we hope to breed up a dairy herd from native cows, and at the same time demonstrate the value of the dairy bred cow as compared to the common cow.

A brief statement of the results of my records follows: (An itemized statement and individual records of cows will be furnished if desired.)

Cost of feed for entire herd for 8 mo. beginning Mar. 1		$137.00
Cash received for butter fat	283.56	
Cash received for 10 head calves	90.00	
Total	$373.56	
Balance		$236.56
Estimated receipts based upon records of scale and Babcock tests for 5 mo. from June 1st		$183.87
Actual cash receipts for butter fat for the same period		181.54
Discrepancy between actual receipts and theoretical amount		$2.33
We brought to the station 60 hens and 4 roosters valued at		$ 30.00

Poultry.

Cost of feed and new stock for the 8 months		57.60
Cash receipts for eggs and chicks	$ 97.91	
Poultry on hand—80 hens and 4 roosters valued	40.00	
Total	$137.91	$87.60
Balance Credit		$80.31

Repairs and Improvements.—Besides repairing and painting the barn and dwelling house and repairing and rebuilding fences, we have built as follows:

1 dairy barn 26x60 inside measure—walls of adobe, roof of corrugated iron.

1 poultry house 13x20 inside measure—walls of adobe and roof of boards (with tar paper and adobe.)

1 smoke house and store room, 14x14 inside measure. Walls and roof same as poultry house.

Details of these buildings will be given in bulletin on adobe building.

Items of expense not otherwise accounted for:

Pasture	$30.00
Water Privilege	30.00
Horse Feed	189.47
Labor	316.37
Total	$565.84

The settlers of this section of the State are vitally interested in the following lines of work: farm dairying; poultry raising; wheat farming; potato raising; family gardening and the growing of fruit and shade trees. Therefore the station should give all the aid possible particularly along these lines.

Respectfully submitted,

J. W. ADAMS,

Superintendent Cheyenne Wells Sub-Station.

REPORT OF ANIMAL HUSBANDRY SECTION.

To the Director:

The following projects were carried on during the past year under State Funds:

1. Ration Experiment with Swine. A continuation of our investigations concerning the value of tankage in swine rations, involving a test of fertilizer tankage for feeding purposes. This year's work ends for the present our work with tankage.

2. Ration Experiment with Lambs. A continuation of our work comparing the feeding of alfalfa hay in self-feeders, with feeding upon the ground; comparing cut or chopped hay with whole hay; and comparing California Feed barley with corn. This ends our tests of the self-feeder for hay. The work with cut hay will be continued during the coming year, and will be enlarged to include a test of granulated hay. California Feed barley will be tested again, and compared with a two-rowed brewing barley.

3. Ration experiments with Steers. A test of California Feed barley in comparison with corn, and in comparison with a mixed

ration. Part of this work will be duplicated the coming year, and a test of granulated alfalfa made.

4. Beef Production in Colorado. A new project begun during the past year, aiming to arrive at the cost of producing an 1,100 pound steer fit for market as a long yearling. Cows were bought in the spring and calved on enclosed range. The calves are now being winter fed. This must be continued another year in order to complete it, possibly two years.

Two bulletins have been issued during the year, numbers 151 and 165 upon "Ration Experiments with Lambs" and "Ration Experiments with Swine."

Inquiries are constantly coming to the office concerning the best rations to use for the various classes of livestock. The work we have done gives us considerable definite information upon various rations, and the work should be continued along these lines.

The poultry work has been conducted independently during the year, and the report of the poultryman follows.

Respectfully submitted,
G. E. MORTON,
Animal Husbandman.

REPORT OF POULTRY SPECIALIST.

To G. E. Morton, Animal Husbandman:

We believed at the beginning of the past year that we might be able to carry out certain projects, such as determining cost of egg and flesh production, etc., but on account of absence from home much of the time, these projects were discontinued.

As it seems more necessary to carry on extension and other outside work than to undertake such projects as mentioned, we are planning an egg-laying contest which should bring a model poultry plant or school into a number of localities in Colorado and show the farmers and poultrymen in these communities the advisability of keeping pure-bred poultry in order to secure the best results and best market prices.

One hundred visitors a month are coming to the Poultry Department, a large percentage of whom are seeking information of some character. Some borrow models of our poultry houses in order to build like them; many have sick fowls; some are in doubt as to which breed of fowls to handle; and we are getting an average of fifty let-

ters a month form all parts of Colorado and other sections of our country asking for information.

We have recently completed a building 96 feet long; part of it 16x18 feet and two stories, to be used as a feed house and office room, the rest of the building, 80x12, consists of ten pens for ten different varieties of poultry for the benefit of our students and visitors who wish to become familiar with the most popular varieties of fowls. In addition we have a work shop and ten colony houses of five different types. Most of these are 8x14 feet in size and are of such patterns as to meet the different needs and demands of different conditions and surroundings. This enables prospective builders to get specifications, cost of material, advantages and disadvantages of different types, etc.

We believe the farmer who is raising some poultry should double his output rather than that others should jump into the business without proper preparation, and to keep this policy in operation we are endeavoring to show him the necessity of keeping the kind of stock the market wants, and the necessity of housing and caring for such stock in a manner to produce satisfactory results.

With our present equipment of buildings, incubators and stock, if we are to continue extension work as in the past, we feel the need of help to carry on the work in our absence. We find it necessary to neglect much office work, which, should be carefully looked after, because of outside work, and are unable to carry on experimental work which our poultrymen are asking for and which would benefit the industry if followed up.

Respectfully submitted,

W. E. VAPLON,

Poultryman.

REPORT OF THE FIELD HORTICULTURIST.

To E. R. Bennett, Horticulturist:

The following is the annual report covering the work in State Fruit Investigations from November, 1909, to November, 1910.

The following approved projects have been worked upon:

1. Shade Crops for Old Apple Orchards.
2. The Season of Bloom of Fruit Trees.
3. The Control of the Brown or Pustular Spot of the Peach.
4. The Thinning of Jonathan and Winesap Apples.

5. The Cold Storage of Jonathan Apples.
6. The Growing of Raspberries in Colorado.

Shade Crops for Old Apple Orchards.—For this purpose a nine-acre orchard near Delta, owned by Mr. Wm. Duling, was secured and eight different legumes sowed, leaving one acre for a check which was clean cultivated. The following legumes were used: field peas, cow peas, crimson clover, winter vetch, red clover, alfalfa, mammoth red clover, and sweet clover. These were all sowed near the tenth of April, 1910.

The conclusions for the season's work, so far as tests of varieties are concerned, in brief, are: 1st—Field peas make a very good growth, if sowed very early, and thus can be reseeded in July by disking in, but for an old bearing orchard, especially where the middles are pretty well shaded, this second crop does not always grow well; 2d—Cow peas were planted twice, the second seeding being done in the latter part of July. Neither planting did well as the seed failed to germinate, due very likely to the cold ground caused by the shade of the trees; 3d—The clovers, winter vetch and alfalfa are at this time the most promising for shading the ground and making a good mat to be turned under later on for green manuring. Of these the winter vetch has the greatest mat and would be the best for a green manure, if plowed under at the present time.

In connection with the foregoing project a cover crop experiment was started in the Excelsior peach orchard at Paonia, Mr. Frank Van Deren, Manager. In this orchard, on July 23d, was sown the following: red clover, crimson clover, fall rye and field peas. Of these the fall rye at the present time appears to be the best for a winter cover crop. The clovers made very little growth and the field peas were but from four to seven inches high and were badly mildewed. It would seem from this that with but one irrigation after the seed was planted that July 23d was too late for the sowing of field peas in a bearing peach orchard.

The Season of Bloom of Fruit Trees.—At first the object of this project was to determine what varieties of apples bloomed near enough together to insure cross pollination. When it was found that the season of bloom for the summer and winter varieties, respectively, bloomed so near together, it was thought best to see what varieties of the important winter ones were self-fertile and also those which were self-sterile. For this purpose about 900 bags were placed on unopened bloom clusters. The freeze on the night of May 16th put an end to this part of the experiment. A record of the number of days that the calyx remained opened was kept for each variety. The minimum

number of days, which was about seven, gives plenty of time for the first codling moth spraying.

The Control of the Brown or Pustular Spot of the Peach.—This trouble was first noticed at Eckert, during the summer of 1908, and during the season of 1909 did a great deal of damage in that locality. A block of peach trees in Mr. A. L. Renolds' orchard, at Eckert, was secured for spraying to find out what kind of spray to use and when best to apply for the control of the trouble. Two applications of Rex lime-sulfur, Bordeaux and home-made lime-sulfur were made, but the May freeze killed every peach in the orchard, so that no conclusions could be made except the effect of the one summer spray (May 25th) on the leaves, which was as follows: With one-half strength Bordeaux (2-5-50) there were some shot holing, perhaps more than from the use of Rex, but not enough to do any particular damage. The Rex lime-sulfur, 1 to 50 with 6 pounds of lime added, did some leaf buring but the injury was not severe. The self-boiled lime-sulfur (10-8-50) did no injury to the leaves whatsoever, and if it proves to have the same fungicidal value as Bordeaux, will no doubt be used in its place.

On August 19th six trees were sprayed in the Henry Teachout peach orchard at Eckert. In this orchard there was a fair crop and not many diseased peaches. The same fungicides were used as in the Reynolds' orchard. The following conclusions were noted. 1st—August 10th this year was the earliest date that peach spot was noticed at Eckert. 2d—That August 19th is too late to spray for its control. 3d—The summer being very dry the trouble did not gain much headway. 4th—That excessive moisture caused either from over irrigation or rains tends to favor the trouble and especially is this true when the trees are close together, thus affording plenty of shade. 5th—The softer the peach the more liable it is to attack.

The Thinning of Jonathan and Winesap Apples.—The object of this project was to determine whether, from a money standpoint, thinning of heavily loaded fruit trees will pay, and if a systematic thinning each year will have something to do to prevent the "off year," especially of the Jonathan. The result of this work has been published in bulletin 170.

The Cold Storage of Jonathan Apples.—As a rule the Jonathan apple does not keep in cold storage so well as it is thought it might, and for this reason an experiment is now being carried on in the Colorado Ice and Cold Storage plant in Denver. The object of the work was to determine if the delayed picking and packing or the delayed storage had anything to do with their keeping qualities.

The Growing of Raspberries in Colorado.—The information secured on this project is being published as bulletin 171.

Incidental Observations Other Than Experimental Projects.—Some time was spent in observations along the line of Arsenical Poisoning of Fruit Trees and injuries done by nitrates in the soil. These are being worked on by Dr. Headden and Professor Sackett.

Winter Injury.—Notes on this work have just been published in bulletin 170.

Orchard Heating.—With good systematic work orchard heaters can be used to good advantage. This was demonstrated on the night of April 15th, when with oil and coal heaters the temperature was raised 6 to 8 degrees, and this was with an outside temperature of about 21 degrees. On this date apple fruit buds were out of danger with a temperature of 29 degrees.

Demonstration Work in Orchard Management.—Demonstrations in pruning, grafting, etc., were given whenever the occasion called for it. About twelve days, not including the time it took for travel, were spent at Palisade helping Mr. G. P. Weldon with his codling moth and other insect spraying experiments.

About a month was spent at the college last winter doing teaching work for Professor Bennett while he was away on institute work.

During the year the following articles have been written for College "News Notes;" The Time for Pruning Peach Trees When Injured by Winter Freezing; Treatment for Winter Injury of Young Apple Trees; Low Headed Trees in the Orchard.

The following projects will be worked upon during the coming year, viz: 1, Shade Crops for Old Apple Orchards; 2, The Season of Bloom of Fruit Trees; 3, The Control of the Brown or Pustular Spot of the Peach; 4, The Thinning of the Jonathan Apple; 5, Cherries in Colorado.

Respectfully submitted,

R. S. HERRICK,

Field Horticulturist.

HORSE BREEDING INVESTIGATION.

To the Director:

I beg to submit the following brief report of the carriage horse breeding experiment as conducted by the Experiment Station in co-operation with the U. S. Department of Agriculture:

Stud Record Summary.—There are in the stud at the present time seventy-five animals, consisting of the following:

1 aged stallion.
1 four-year-old stallion.
1 three-year-old stallion.
3 two-year-old stallions.
20 aged mares in service.
6 four-year-old mares in service.
5 three-year-old mares in service.
1 four-year-old gelding.
6 two-year-old fillies.
7 yearling colts.
7 yearling colts.
6 yearling fillies.
12 male foals.
6 female foals.

75 Total number in stud.

There have been no additions made to the brood mare ranks during the present season except those developed at the station. One two-year-old stallion, Red Cedar, was pruchased during the season for use in mating with the Carmon fillies. The retention of this stallion in the stud depends upon his development as an individual, and his ability to nick well with the Carmon blood.

One valuable mare, Wyoming, died on September 10, 1910, the immediate cause of death being pulmonary gangrene. This mare was a very valuable brood mare and her loss is regretted.

Sale of Surplus Animals.—The Board of Survey, in its annual report dated August 19, 1910, recommends that the following animals be disposed of at public auction as their retention for breeding purpoises is undesirable.

1 four-year-old bay Gelding, Alva.
1 two-year-old black mare, Carnation.
1 two-year-old bay mare, Cora.

1 two-year-old bay mare, Columbia.
1 yearling bay cold, Dandy Jim.
1 yearling bay colt, Denver.
1 yearling bay filly, Dolly Wilkes.
1 yearling bay filly, Dorothy.

All the above-named animals are the property of the station, with the exception of the two-year-old mare, Carnation, which is the property of the Deparment of Agriculture. I recommend that these animals be sold at the earliest convenient date.

The progress made during the past season is very satisfactory. Out of eighteen foals being raised, twelve are male foals and six are fillies. The type is uniform with very few possible exceptions. Especially good results have been attained on the first cross of Carmon on the "King," "Red Cloud" and "Chester Dare" blood—these mares being of American Saddle breeding. The result of this mating has increased the size ordinarily found in the Kentucky saddle horse, yet retaining the quality for which the breed is renowned. The development of these foals will be watched with great interest.

The difficult problem facing the experiment at the present time is obtaining a satisfactory stallion to follow Carmon at the head of the stud. Carmon will be retained, but it is very important to secure a stallion of the proper type and breeding to follow on Carmon's progeny. The Expert-in-Charge has spent considerable time during the past two months endeavoring to locate such a stallion, also some satisfactory standard-bred mares for use in the stud. Some mares have been located and it is quite likely some additions to the stud will be made in the near future. It is very important that no additions be made unless the animals purchased are superior individuals of pure breeding along known lines. In an important experiment of this kind it is better to have a few specimens of known value rather than an unlimited number of indiscriminately bred animals.

The result of the mating of Carmon mares to the Government Morgan stallion, General Gates, at Middlebury, Vermont, has resulted in the production of very superior foals. This blood should be of extreme value in the development of the ultimate type of carriage horse.

Summary.—The Board of Survey in its annual report to the Secretary of Agriculture reported that "the stud was found in excellent condition, and that the standard, judged by the improvement in the young stock and the appearance of the foals this year, is steadily being raised."

The standard of excellence at the Horse Breeding Station is being maintaind by a strict process of selection. The station is carefully

inspected each year and inferior animals are eliminated. This results in raising the standard of the animals at the station. The various producing families are carefully observed, and those mares which consistently produce inferior progeny are discarded along with their progeny. This process of strict selection will utimiately result in the retention only of those families which consistently produce individuals of uniformly superior merit, adhering to a definite type.

Respectfully submitted,

J. O. WILLIAMS,

Expert-in-Charge.

REPORT OF BACTERIOLOGIST.

To the Director:

I have the honor to submit herewith the annual report of the Bacteriological Section of the Experiment Station for the year 1910.

Under the provisions of the Adams Fund, four lines of investigation have been pursued during the year which is about to close. Two of these were carried over from last year, one of which has been completed, and two new studies have been begun.

Project 1, Bacterial Disease of Alfalfa.—The results of this investigation have shown the stem blight of alfalfa to be due to a germ, to which the writer has given the name, Pseudomonas medicaginis, n. sp. The causal organism, presumably, lives in the soil, and enters the plants with soil, through stems which are cracked and split by late spring freezing. The disease is so serious in some localities as to cause the loss of 85 per cent of the first cutting. It was especially serious in the vicinity of Rocky Ford last spring, and was also reported as occurring in Eagle, Garfield, Mesa, Delta, Denver, Morgan and Larimer Counties. As a means of control, we have recommended that the diseased alfalfa be clipped as soon as the danger from late spring frosts is past, thereby ridding the plants of the blighted portions, and affording an opportunity for the early growth of a new cutting. Where this has been practiced, the results have been entirely satisfactory, and the tonnage has been considerably greater than that from areas which were not clipped. Our variety test work which we have been carrying on at Gypsum, for the purpose of obtaining disease resistant varieties, has been transferred to Rocky Ford. This has seemed desirable because of the difficulty we have experienced in getting the services of a

competent person to look after the field plats. Professor Blinn has very kindly consented to include this work with similar studies which he is carrying on. Through the courtesy of Mr. J. M. Westgate, of the United States Department of Agriculture, we have secured fourteen new strains of hardy alfalfa, which have been planted at Rocky Ford. No entirely disease resistant varieties have been obtained up to the present time.

With the exception of the field work mentioned above, this project has been completed, and the results of the whole invesigation have been published in bulletin 158, "A Bacterial Disease of Alfalfa." April, 1910. A popular edition of Bulletin 158 has been issued as Bulletin 159, "Stem Blight, A New Disease of Alfalfa."

Project 2, Bacteriological Studies of Alkali Soils.—This line of investigation, as originally outlined, was intended to include the different functional activities of soil bacteria as related to agricultural practices, and as possibly modified and influenced by our peculiar climatic and alkaline soil conditions. Thus far, our work has been confined to a study of the nitrogen fixing flora of certain soils which Dr. Headden has shown to contain excessive nitrates, it being our purpose to establish, if possible, some definite relation between the high nitrates and the nitrogen fixing bacteria, whereby we should be able to explain the presence of the nitrates. During the past year we have examined forty samples of soil of widely separated sections of the State, where the nitrates have been so abundant as to cause serious loss to the agricultural interests. Thirty-nine of these samples have possessed very marked nitrogen fixing properties, and pure cultures of Azotobacter, the nitrogen fixing micro-organism, have been isolated readily.

We have established with a reasonable degree of certainty the relation between the characteristic brown color of the soil which frequently accompanies the nitre trouble, described by Dr. Headden as "brown spots," or "black alkali," and the presence of Azotobacter. We have produced the color experimentally on sand where it seems to be due to the brown pigment incident to the growth of certain nitrogen fixing species which are very abundant in some of the soils in question.

Technical studies have been carried on along the following lines: the germicidal action of metalic copper as a possible remedy for the trouble; the influence of different combinations of carbon as found in manite, filter paper, cotton, etc., upon nitrogen fixation by pure cultures; the relation of aeration, chemical reaction, quantity of carbohydrate, substratum, etc., to the amount of nitrogen fixed.

Experiments are now in progress to determine the relation of the different soil constituents, peculiar to our soils, to nitrogen fixation.

We hope by this means to throw some light upon the apparently extreme and unprecedented activity of the Azotobacter, whereby we shall be able to explain more satisfactorily the high nitrates. We are also endeavoring to produce these high nitrates *in situ* in sterilized soil, which has been inoculated with infected soil; if by simulating field conditions thus, we are able to demonstrate the accumulation of large quantities of nitrogen, there should be no longer any question as to the part which Azotobacter plays in the high nitrogen content of certain Colorado soils.

Project 3, *Holdover Blight in the Pear, Apple, etc.*—A new line of investigation has been called for in regard to what is known as "holdover" blight in the pear, apple, quince and apricot. This has come about through a difference of opinion among fruit growers, as to whether the germs of blight can live through the winter in the diseased limbs and twigs and be active in the spring to renew the blight. Our studies for the past spring showed 41 per cent. of the diseased twigs to contain living germs on March 1, 1910. Observations should be made for at least two more seasons to confirm these findings.

Project 4, *Raspberry Yellows.*—For several years past the raspberry growers in the vicinity of Loveland, Colorado, have complained that the canes were small, brittle, discolored, and that the young shoots in the spring showed a tendency to turn yellow and shrivel.

A number of factors seem to be responsible for this condition of the raspberries, among which may be mentioned winter injury, spring freezing, methods of covering, and the presence of the fungus, Sphaerella rubina. The fungus attack has been prevented entirely the past season by the use of Bordeaux mixture and several different methods of protecting the canes during the coming winter have been carried out on the experimental berries at Loveland. The question is such a complicated one that it will probably require at least two seasons more before we shall be in a position to suggest remedial measures.

A popular bulletin along lines of Dairy Bacteriology has been prepared and published as No. 156, entitled "Butter Making, Clean Milk and Commercial Starters."

Respectfully submitted,

WALTER G. SACKETT,

Bacteriologist.

REPORT OF BOTANIST.

To the Director:

During the year just ending the following projects have been under investigation:

Adams Fund.—Black Root of Strawberry.—This rather indefinite trouble is characterized by the blackening and ultimate decay of the roots of plants during the second season after setting a plantation. It usually starts at the season when new growth is beginning in spring and affected plants may put forth leaves and blossoms only to wilt and die later on. The trouble appears to be closely associated with winter injury and unfavorable soil conditions. Attempts have been made during the past growing season to determine the possible presence of parasitic fungi as one of the causes of this trouble. Plants have been grown in sterilized soil and in soil from fields where the trouble existed but thus far no positive results pointing to any parasitic organism as the cause have been secured. The arrival of some special glassware for growing the plants under sterile conditions will enable me to further investigate this phase of the subject. No publications on this subject have been issued.

Special Fund.—Five years ago last spring forty-eight lots of Black Locust and Hardy Catalpa trees were sent out for co-operative planting in different parts of the state. During the past season two weeks were spent in trips of inspection of these plantations. Upon receipt of further data from some of these parties it is my intention to submit a report covering this experiment. This is expected to be done by the expiration of the present year. On the whole this kind of co-operative experimenting has proven unsatisfactory, due largely to frequent changes in ownership of the land planted to these trees and the failure of those in charge to follow the instructions of this department. A few plantations, however, offer much encouragement in the way in which they have been handled and in the growth the trees have made.

This experiment was originally planned to extend over a period of ten years.

Some further experiments in the control of the dandelion pest in lawns were carried on during the past season. This work was not taken up under the head of a project. It was learned that a solution of commercial iron sulphate of 15 per cent. strength is as effective as a 20 per cent. solution. One and a quarter pounds of iron sulphate dissolved in each gallon of water gives approximately such a solution.

In the past season spraying was begun in April. The results were not so successful as those of last season when the first application was made in late summer. The varied results secured during the past season indicate that the conditions for success are not at all uniform and that careful study and experimenting is necessary to reveal the most favorable time and conditions for this work.

Respectfully submitted,

B. O. LONGYEAR,

Botanist.

REPORT OF THE CHEMICAL SECTION.

To the Director:

The Chemical Section has no project on either the Hatch or State funds at the present time. On the Adams fund we have the following projects:

First—The relation of the waters of the San Luis Valley, especially those of the Rio Grande, to the alkali question.

Second—The relation, if any, of the alkali in our soils to the arsenical poisoning of fruit trees.

Third—The occurrence and formation of nitrates in our alkaline soils. This subject includes the effects of nitrates on fruit and incidentally other trees, also its effect on general crops—the sugar beet in particular.

Fourth—A study of Colorado fodders.

The status of the work on these projects is as follows: The first project is well advanced, much field work has been done and all of the analytical work consequent thereto has been completed. So far as I can now see there is a small amount of field work which can advantageously be done before this project may be considered as completed.

The second project is practically completed and already reported on in Bulletins 131 and 157. There are some experiments which were started during the progress of the work the results of which could not be made available at the time that Bulletin 157 was written. The work on this project is already completed, with the exception of a few delayed results and observations, as I have indicated. I do not wish to report this project wholly completed, as constant observation in the orchards and unfinished experiments may open up new questions in

this connection. The expense of keeping this project as an open one is nominal.

The third project, the nitre problem, is at the present time receiving our undivided attention. All of our energies are concentrated upon the study of the occurrence of these salts, their formation and their effect upon sugar beets. Their effects upon fruit and shade trees are so evident that the question is practically closed by the death of the trees which ensues within a few weeks, or at longest within a few months after the concentration of the nitrates becomes sufficient to produce visible effects. The progress of this difficulty during the past season in some portions of the State has been very marked, and I may say disastrous. The study of this subject has already resulted in the publication of Bulletins 155 and 160—the former in February and the latter in May of this year.

The fourth project, the study of Colorado fodders, is at present held in abeyance because the nitre problem seems to be not only a very interesting scientific problem, but of the very greatest, if not vital importance to several sections of the State. Cattle will continue to feed and fatten on our fodders grown under the system of irrigation practiced in our mountain parks just as they have done in the past whether the cause for the excellent results be discovered or not. It will not matter very much from a practical standpoint whether our criteria for judging the value of fodders be greatly improved or not, but not so with the nitre question. If I am correct in my views that this is one of the principal causes for the anomalous agricultural results already observed by very many of our people, it is of vital importance to the State, as well as of the highest interest, that this problem should be solved quickly. The questions pertaining to our fodders are exceedingly interesting, but they involve no element of danger as yet discovered.

These statements are made to indicate clearly that I have not postponed the study of the fodders because I have come to believe such study to be of too little scientific or practical value to justify its prosecution, but simply that I have discontinued it because the nitre problem is, perhaps, of even greater scientific, and is certainly of very much greater immediate and practical importance.

Nothing has been published on the subject of Colorado fodders during the year just ending, but several bulletins, viz., 39, 93, 124, 125 and 135 have appeared during former years. Most of this work was done before the Adams fund was created. This project is, however, a continuation of the project extended to our fodders grown under the system of mountain irrigation, a study of which, as a condition of prime importance, is necessarily involved.

The first three projects enumerated have been the outgrowth of a more general study begun almost immediately upon my assuming the duties of Chemist in charge of this Section of the Experiment Station. At that time this question was considered of great importance, and I gathered many samples of alkali in various parts of the State and studied some of our alkali soils both in the laboratory and in the field, growing four successive crops on a soil very high in alkali and without drainage.

The conclusion of that study was summed up in the sentence "That the alkali question in Colorado is one of drainage." I still think that this is wholly true of all the features of the problem as they then presented themselves and of the same features at the present time. I have not at any time presented a discussion of the general question of alkalies in Colorado, because I believe that the question is understood by the public at large, and yet there are a few phases of it which might justify a little further study and a presentation of the facts gathered.

Bulletins published by this Section during the year are, No. 155, "The Fixation of Nitrogen in Some Colorado Soils;" No. 157, "Arsenical Poisoning of Fruit Trees;" No. 160, "Nitrates in the Soil, An Explanation of So-Called Black Alkali or Brown Spots;" and a manuscript presented by Mr. Douglass on the Deterioration of Farmyard Manures under Colorado Conditions.

The following persons have been engaged in Adams work as assistants during the whole or a part of the year; Prof. F. C. Alford; Mr. Earl Douglass throughout the year; Mr. C. E. Vail and Mr. J. C. Summers a part of the year. Professor Alford was engaged on Adams work for a short time during the summer vacation. Mr. Vail has duties in connection with the College during a portion of the school year, depending upon the schedule, approximately for one-half of the year. Mr. Summers entered upon his duties about June 15, 1910, and is engaged exclusively on station work. Mr. Douglass has been with us for the past ten years.

My college duties are almost wholly confined to the executive affairs of the Chemical Department and I do but very little teaching.

Before closing this report I wish to gratefully mention the interest shown in my work by the Holly and American Beet Sugar Companies operating in the Arkansas Valley, and their willingness to help me both in the field and laboratory. My acknowledgements are especially due to the officers of the American Beet Sugar Company from whom I have received, both in the agricultural and operating departments, many courtesies and material aid.

Respectfully submitted,

WM. P. HEADDEN, Chemist.

REPORT OF ENTOMOLOGICAL SECTION.

To the Director:

I am presenting herewith my annual report of the Entomological Section of the Experiment Station for the year 1910.

The projects carried on in this section during the past year have been upon the Adams and the Hatch funds chiefly as given below.

ADAMS FUND PROJECT.

Plant Louse Investigations.—Is the only project I have had, the expenses of which have been paid from the Adams fund. In our studies of these lice we have gathered a large number of records as to food-plants, dates of spring and fall migrations, dates of the hatching of the eggs in the spring, dates of the appearance of the sexual forms, and the like. We have also worked out the alternate hosts or food-habits of some species not before recorded. Mr. L. C. Bragg has proven beyond a doubt that the fall migrants of *Pemphigus betae* go to cottonwood trees where the sexual forms are deposited upon the bark of the trunks

Both Mr. Bragg and the writer have made numerous observations upon the migratory habits of *Aphis cornifoliae* Fitch, which leaves the dogwood, *Svida* (*Cornus*) *stolenifera riparia,* in the spring and takes up its abode chiefly upon the sunflower (*Helianthus*) leaves, and then sends return migrants from the sunflowers to dogwood again in the fall. It also seems most certain that *A. helianthi* Monell, and *A. gillettei* Cowen are both synonymous with *cornifoliae* Fitch.

Many descriptions of new species have been made in manuscript, as well as numerous descriptions of sexual and other forms of described species, and nearly all that have been described have been carefully drawn in color from living specimens for future reference by Miss M. A. Palmer.

Several technical papers giving the results of this work have been published in the "Journal of Economic Entomology."

I believe the work should be actively continued for another year at least, looking to the publication of a comparatively complete list of Colorado Aphididae with their food plants and migratory habits so far as we have been able to determine them.

HATCH PROJECTS.

Codling Moth Experiments.—To determine more certainly the number of broods of this insect in the principal fruit sections of the

State, records have been collected through the season in Mesa County by Mr. George P. Weldon.

Experimental spraying has been carried on to get additional data upon the comparative importance of the different periods of spraying throughout the season, and upon the comparative values of the different strengths of spray materials, and also to determine the value of sulfide of arsenic in comparison with lead arsenate for the control of the codling moth. Some of this work was supported from the State fund for Horticultural Investigations.

Miscellaneous Insect Pests.—The work on this project has been mainly directed to the determination of early spring remedies for orchard plant lice, the working out of the habits of a new corn rootworm, *Diabrotica virgifera* Lec., and var. *filicornis* Horn, which have done serious injury in limited localities in Colorado for the past two summers, at least, and a study of our grasshopper problems. Under this head Professor Johnson also has carried on some further observations and experiments upon life habits and control of potato insects, especially the flea-beetle, *Epitrix cucumeris,* and the potato beetle. *Leptinotarsa decemlineata.*

Insect Collection.—The work of collecting insects for the purpose of getting together the insect fauna of the State and having it systematically arranged for reference has been continued, but only in a small way.

The Experimental Orchard.—Has served for some of our experiments with insecticides and for the destruction of plant lice.

The projects under the Hatch fund that I am not planning to continue another year are Potato Insects, Insect Collection and Experimental Orchard.

STATE APPROPRIATION.

Fruit Investigations.—Under the State Appropriation for Horticultural Investigations I have had general oversight and planning of the field work in Entomology that has been carried on by Mr. Geo. P. Weldon on the Western Slope. Mr. Weldon's report is appended hereto.

Respectfully submitted,

C. P. GILLETTE,

Entomologist.

REPORT OF FIELD ENTOMOLOGIST.

To C. P. Gillette, Entomologist:

Projects for the year consisted in codling moth, plant louse, peach twig-borer, San Jose scale and mite work. None of these projects was entirely completed and it would seem desirable to continue the work along the same lines; in some cases for a number of years.

The codling moth work required much attention throughout the season. Probably never before were demands upon the time of the field men by the orchardists so great. While the fruit crop as a whole was a wormy one, there are a number of orchardists in the Valley, who are willing to testify that their eagerness to listen to the advice of those who are spending their entire time toward devising means of control of these, as well as other pests, and to follow out instructions as to the proper time to spray and the best methods to pursue, resulted in their being able to keep the fruit comparatively clean, even though the season was an unfavorable one.

While we regret the fact that this year's crop of apples was so wormy we feel that many valuable points in regard to the control of this insect were gained. From the standpoint of the orchardists the season brought some fruitful results. The idea that codling moth control is only a matter of spraying most any time and in an indifferent way, should no longer have a place in the mind of any intelligent orchardist. It was only by very careful spraying at the right time, that the great majority of orchardists who were successful in this work, met with success this year. Until the codling moth is much scarcer in Western Slope orchards, we will urge the use of other means of control besides spraying, such as the scraping off of all loose bark from the trees in the fall or early spring, and the destruction of hibernating larvae found beneath; the destruction of larvae hibernating in packing houses; banding of the trees and collection of larvae, as well as any other means which may be employed in decreasing the present abundance of worms.

There is need for very careful life history work on the codling moth, as well as extensive experiments with arsenate of lead and other insecticides. Tests show that arsenate of lead acts so slowly that apples are always badly specked when numerous worms have been trying to enter the sides, also it is not adhesive enough for some varieties of apples—for example, Ben Davis—this variety has an oily skin and no matter how thorough the spraying may be done the liquid applied tends to collect in large drops instead of forming an even coat-

ing of smaller ones over the entire surface of the fruit. Such varieties as the Winesap are much more easily coated simply because the skin is not so oily and the tendency for the water to run off is therefore not so great.

Plant louse investigations are carried on as the abundance of any certain species during the season requires. The past season was noted by the very severe attack of green peach aphis and some helpful points in regard to the control of this pest were gained through experimental work.

The peach twig-borer work of the season consisted almost entirely of a test with different insecticides used in the spring, and some beneficial results were obtained from this experiment. A bulletin on peach insects soon to be issued will treat fully of these two pests.

Mite work this season brought out the very important fact that a dormant spray of lime and sulfur applied in the spring, will control brown mite very effectively, but is of no value in the control of the red spider.

The San Jose scale has not been found hard to control wherever it has occurred, and orchardists will probably experience less trouble in controlling this pest by means of a spray, than codling moth, peach aphis, or some other pests which we have had with us for a number of years.

The work of this office is steadily on the increase; the problems to be solved are many and of great importance; the efficiency can be greatly impaired by the lack of funds to carry on important projects.

Respectfully submitted,

GEORGE P. WELDON,
Field Entomologist.

REPORT OF HORTICULTURAL SECTION.

To the Director:

I have the honor to make the following brief statement of the work of the Horticultural Section for the past year.

The work has been divided between three men, Mr. C. L. Fitch, the Potato Specialist, has had charge of the potato investigations under the special state funds which were given us for that purpose. Mr. R. S. Herrick has had charge of the fruit investigation and has been located most of the year at Delta, Colorado. The investigations at Fort Collins and the management of the office have been in my

charge since August 1, 1909. The reports of Mr. Herrick and Mr. Fitch are submitted separately.

The plans at Fort Collins are as follows:

Asparagus Investigation.—Although there is not enough asparagus grown in Colorado to supply the local demand we believe that this should be one of our important truck crops, both for local supply and for canning purposes. With the idea in mind of investigating this industry and overcoming some of the difficulties that present themselves in its culture, we have started a small plot of asparagus. During April a plot of about a quarter of an acre was sown with three of the standard varieties of asparagus. This asparagus nursery has done particularly well so far. Next spring the permanent plot can be made. This investigation will require a little work each year for several years, and we believe that it is well worth carrying forward.

The asparagus investigation is being carried on by funds from the State Fruit Appropriation. The expense so far has been very light and will be pretty nearly self-supporting after the plots are established.

Cover Crops for Orchards.—One of the most serious problems confronting the orchardists of Colorado is that of maintaining the physical condition of the soils in the orchards. Clean cultivation has been the rule and we believe this has been carried on to the detriment of the orchards. Experiments along lines to determine the best crop to grow between the trees for the benefit of the soil, have been started both here and at Fort Collins, by myself, and at Delta, by Mr. Herrick. Plots in the old orchard on the west college farm and in the young orchard in the same place were planted to red clover, crimson clover, field peas, cow peas, alsike and winter vetch. Two plantings were made, one in May, the other in July. Owing to the invasion of grasshoppers from outside fields and inability to secure water for these orchards both plantings were practically failures. It is thought advisable to carry on this investigation another year, both here and on the west slope.

The Cover Crop project was carried on by State Fruit Appropriation funds.

Cabbage Investigation.—This project was started with a hope of working out both a scientific principle and eliminating a difficulty that has been experienced with cabbage growers at Greeley. The Cross cabbage, which is almost universally used in that district, is a hybrid between a pointed early cabbage, the Winningstadt, and a flat later cabbage, the Flat Dutch. Since the introduction of this variety some ten or twelve yeare ago the seed has been grown at Greeley and while the cabbage is a valuable one, there has always been a tendency for

a certain per cent. of the crop to revert back to either one or the other parents. It is thought that this tendency might be eliminated by saving seed separately from many different plants. Seeds were saved during the season of 1909 and were planted in the college gardens in separate plots this season. The work so far has been very satisfactory. Four out of about fifty plots gave heads, all of which were true to type. These have been saved from which to get seed to carry the experiment further.

This project was carried on by Hatch funds.

The Vegetable Garden.—The vegetable gardening industry of the State is one of the important agricultural industries of Colorado. A great deal of the correspondence in the line of information is in regard to various crops for the vegetable garden. In order to have material for experimenting and demonstrating work it was thought advisable to establish and maintain vegetable gardens. In carrying out this project about three acres of ground west of the Veterinary Buildings, on Laurel Street, were planted to the various garden vegetables that are grown in this climate. It was aimed to have in this garden some of the standard varieties of all of the vegetables that could be profitably grown here, partly as a demonstration and partly for the purpose of experimenting with various problems that came up. Several of the other projects as the asparagus, cauliflower, cabbage, etc., were carried on in connection with this work. The results have been gratifying and it is hoped to continue the work in the future.

This project was carried on under the Fruit Appropriation, but can be made practically self-supporting after the garden is well established.

Cauliflower Investigation in High Altitudes.—Cauliflower is one of the crops that seems to be particularly adapted to the high altitude agricultural districts of Colorado. As a matter of demonstration and experiment, cauliflower plants were grown at the college greenhouses, for use in this experiment. About 1,000 were sent to Grand County and about the same to Del Norte. The remainder, something over 1,000 plants, were planted in the college gardens at Fort Collins. Those sent to Grand County came to an untimely end as a result of ground squirrel depredations. The season in San Luis Valley was not favorable, yet the plants sent there made a very good showing, though not so good as crops grown there in former years. Those planted in the college gardens were entirely sucessful and are being sold and used for experimental purposes at the present time.

This project was carried on under the special Fruit Appropriation.

Orchard Investigation.—The only orchards connected with the Experiment Station at Fort Collins are some old trees on the west farm and a few old trees near the house occupied by Prof. Keyser. Both of these old orchards are practically useless, owing to having been planted too close together, and the fact that the varieties are undesirable. In order to determine the best method of handling an orchard in this district and to work on the many orchard problems that are continually coming up, such as cover crops, pruning, spraying, grafting, and a method of establishing the best kind of a tree, it was thought desirable to plant a small orchard on the college grounds. Accordingly an orchard was set consisting of 90 cherry trees, including the standard varieties of sour cherries, and 90 plum trees and the same number of apple. Weather conditions have been decidedly unfavorable for this work the past season, yet the trees have made very satisfactory growth where uninjured by grasshoppers. Along with this work a nursery has been started and about 200 apple root grafts have been grown. It is hoped to carry this work further another year and make it include some of the nursery and young tree problems that are troubling the growers of Colorado.

This project was carried on under the Hatch fund.

Raspberry Investigation.—It was thought desirable to investigate and write up a short description of the raspberry industry in Colorado. With this in mind some investigation has been made along this line and a bulletin is about to be published.

This work was carried on under the State Appropriation.

Cherry Investigation.—It was thought advisable to take up the investigation of the cherry industry of the State for the purpose of writing a short bulletin particularly for the benefit of new comers the same as with the raspberry industry. Owing to lack of time this investigation has received comparatively little attention up to the present. It is hoped to carry this investigation on the coming year and possibly issue a bulletin during the coming winter or spring.

This project is to be carried on under the Fruit Appropriation of the State.

By the aid of the Potato Appropriation, a model potato storage cellar hase been made on the college farm. This cellar is one of the buildings needed on all of the potato ranches of Colorado, and is a valuable building for any farm place. In building this it was aimed to establish a model that might be used by the growers of the State.

The time of the writer during the past year has been divided up between the work of these various projects, the executive work of the department, correspondence, teaching and extension work. It is difficult to say just how much time has been devoted to each of these

branches of the work. About 1,000 letters have been written during the past year. Practically two months' time has been devoted to institute work in the State. The demands of the college and execuive work of the department have taken up a larger share of the time than is desirable, but this cannot well be avoided. On the whole the work of the past year has been fairly satisfactory from our standpoint. The amount of work done has been limited by the amount of time that could be devoted to the various projects. Both Mr. Fitch and Mr. Herrick have carried their work along in a very efficient manner.

I strongly recommend that Mr. Julius Erdman, our greenhouse manager, and Mr. S. V. Smith, the assistant in horticulture, both be placed on the Station Staff.

We believe the projects outlined that have not been completed are well worth continuing in the future. This section has in process of writing, bulletins on the "Colorado Potato," by Fitch and Bennett; "The Irish Potato—A Study of Productiveness and Degeneracy in the Pearl Variety," by Mr. Fitch; "Fruit Notes," by Mr. Herrick; "The Raspberry Industry," by Herrick and Bennett, and "Garden Notes of 1910," by Bennett.

Respectfully submitted,

E. R. BENNETT,

Horticulturist.

REPORT OF THE VETERINARY SECTION.

To the Director:

According to statistics found in the Year Book of the Department of Agriculture for 1910, there is in the State of Colorado, a total valuation of $73,362,000.00 in horses, mules, cattle, sheep and swine. This does not include poultry and other animals, nor the revenue from our domesticated animals.

It has been estimated in some of the states that there is a loss on the average of about two and one-half per cent from preventable diseases. On account of the heavy loss in Colorado from poisonous plants this estimate would doubtless be too low.

Necrotic Stomatitis.—Under this project we did field and laboratory work during the lamb feeding season last winter. We are under obligation to Senator W. A. Drake for assistance given us in furnishing animals for experiment, for information as to the handling of diseased bands of sheep, and location of the same. Under this project we have studied both "lip" and "leg diseases" of sheep

and "sore mouth disease" of hogs, they being caused by the same specific micro-organism. This disease of sheep, because of the seemingly necessary quarantine regulations imposed, has been a serious handicap to the lamb feeding industry of the State. The contention of the lamb feeders has been that most of the sore lips of lambs in this State is not the real necrotic condition, and that while it has been known here for many years, it has never caused any loss, and further that the quarantine of such animals is unjust and unnecessary. In eleven out of fourteen bands of sheep affected the specific organism has been isolated, in the others only varieties of pus organism were found. It is our wish that we be given funds with which to continue this investigation, as it means much to the lamb feeding industry of the State. We have not progressed far enough in the work to warrant the giving out of information in the form of a bulletin.

Diseases of Poultry.—We have been working on diseases of poultry, and have discovered that very little is known about the diseases common to poultry in this State. It has also been determined that there are in this State several of the most deadly diseases of poultry, among them black head disease of turkeys, cholera of chickens, and several parasitic diseases. These diseases can in most instances be prevented, and several practical bulletins would be of much value. A bulletin on Poultry Diseases is now in preparation.

Rabies.—The eastern portion of the State, north of Pueblo, is generally infected with rabies. Dr. B. F. Kaupp has examined the brains of 66 rabid animals in the pathological laboratory in the last year. Many animals have died from being bitten by rabid dogs, coyotes and wolves. Quite a number of people have been bitten, and obliged to go away and take the Pasteur treatment. A bulletin on Rabies was issued in August last.

We are ready and willing to do more work for the State in the identification and control of animal diseases, and we trust that we may be provided with funds which will make this possible.

Respectfully submitted,

GEO. H. GLOVER,

Veterinarian.

ANNUAL REPORT OF SUPERINTENDENT OF EXTENSION.

To the President:

The report of such of the activities of this branch of the College work for the year ending Nov. 1, 1910 as can be tabulated is as follows:

Farmers' Institute Meeting (1 to 6 sessions	89	Total attendance	22,566
Train Institutes (29 stops)	29	Total attendance	4,850
Organizing Boys' and Girls' Agricultural Clubs	96	Total attendance	3,740
Farmers' Short Courses, 1 week			
Housekeepers' Short Courses, 1 week		Total attendance	215
Colorado Farmers' Congress		Delegates	140
*Normal Institute (1 to 2 weeks each)	13	Total attendance	1,213
Total Attendance			32,839

Farmers' Institutes—The total number of Farmers' Institutes held has been 89, with a total of 170 sessions, and an aggregate attendance of all sessions of 22,566. Thirty-one speakers from the College and 4 outside speakers have assisted in this work. All railroads, except the Burlington and the Missouri Pacific, have given free transportation to attend Farmers' Institutes to some of our speakers, and most of them have furnished transportation to all of them.

The demand for Farmers' Institute work is greater than can be met with the available funds, and the work has been handicapped because of the inability of the Superintendent to command the time of the members of the faculty and Experiment Station staff as fully as he could wish. The increased demands made by the College and Experiment Station have rendered it impossible for faculty members to spend much time in extension work off the campus. It is hoped that the new plan of organization of the College work, which is now being put into operation will enable the Superintendent of Agricultural Extension to plan his work with more certainty than heretofore.

It is believed that local organizations to carry on the Farmers' Institute work should be formed as rapidly and as extensively as possible, so as to place the responsibilities for the success of these Institutes in the community for which the institute is held, rather than in

*This work was conducted on College funds under the faculty committee of Rural Education, of which Professor S. A. Johnson is Chairman. The work was carried on by Professors Johnson, Longyear, Rausch, Allison and Mr. Frear. Credit for this work does not appear in the tabulation of Extension Work by individuals, which is attached to this report.

this Department. It is hoped by this means to work up a much better local support for the institutes and to develop local men by giving them a place on each program. It is believed that if this work is carried on actively for the next two years the State will be in a position to reasonably ask adequate county support for the Farmers' Institute movement, and thereby remove a considerable burden from the College and place it where it logically belongs.

It will be necessary as soon as possible to increase the staff and give the Superintendent of Agricultural Extension a small force, possibly not more than two at present, on whom he can count for assistance the greater part of their time. Under our form of organization these will be connected with some department, but will give practically all their time to extension work. One of these should be in the department of Household Economics.

An effort should be made to reach all portions of the State with Farmers' Institute work and to assure local organization to take charge of this work under the direction of the Superintendent of Agricultural Extension.

Women's institutes and institutes for boys and girls should be added.

Train Institutes.—A "Potato Special" train institute was conducted by the Agricultural College in connection with the Denver and Rio Grande Railroad from April 11 to 20, 1910, making 29 stops, the meetings being attended by 2,770 adults and 2080 children, a total attendance of 4,850. These "Agricultural Specials" have come to be a permanent part of the extension work of the College and result in great good to the district through which they pass. It is the cheapest means of extension afforded the College.

In a recent conversation with your Superintendent of Agricultural Extension, Mr. F. A. Wadleigh of the Denver and Rio Grande Railroad, expressed himself as being greatly gratified with the results of the three potato specials operated on their lines, making the statement that in two years the tonnage of potatoes shipped from their lines in Colorado, was very much more than doubled, and expressing his opinion that by far the greater share of this increase should be attributed directly to the work of these potato specials. A certain amount of the interest aroused by these trains has been due to their novelty. Insofar as this is true this interest cannot be expected to be permanently maintained, but disregarding this feature it remains true that the "Agricultural Special" train affords the College an inexpensive means of reaching a large number of people in a very short time, and for this reason these trains should be undertaken as often as practicable, and as the co-operation of the railroads of the State can be secured.

Boys' and Girls' Agricultural Clubs.—During the spring of 1910

Professor Cottrell, Principal Netherton and Mr. Vaplon of the College visited 96 schools, talking to 3,740 boys and girls with reference to the organization of Boys' and Girls' Agricultural Clubs, in in accordance with plans contained in Farmers' Institute Circular No. 1 of April 1910, which circular accompanies this report and is made a part of it. Fifty-two of these clubs were formed, many of these being formed in the "plains or dry farming" districts of the State. Because of the change in the Superintendent of Agricultural Extension in this Institution and because of an unusually severe season a considerable number of these clubs did not succeed in growing enough products to exhibit. Sixteen clubs are now active and have made exhibits and it is believed that these clubs have resulted in the greatest value to their communities.

The State Exhibit of products of these clubs will be held in Fort Collins during the week of January 9 to 14, 1911, instead of Denver according to the original plan as published in the above mentioned circular. The reason for making this change will be found in the report of your Superintendent for the work of the month of October, 1910.

This work should be carried on and extended to cover practically the whole State, but it will be necessary to place it in charge of some one whose sole business shall be to have an intimate acquaintance with the rural schools of the State, and to work up the Boys' and Girls' Clubs. The proper conduct of these clubs involves too much detail to make them practicable to handle solely from this office so long as it is necessary for the superintendent to be away from the office the greater part of his time. It is believed that this will be a proper part of the activities of the rural school visitors whom it is hoped the College will be able to employ during the next biennium.

Short Courses.—In the opinion of your Superintendent the work of the College should be extended by means of special short courses, or movable schools as rapidly as possible and it is hoped that a considerable number of these may be undertaken during the next two years. The plan adopted should be that of confining these schools to a single subject or a small group of closely related subjects, to furnish specialists in these subjects and study them carefully for one week with a class limited in number, so as to allow good work to be done. Such classes may be made self-sustaining by a reasonable registration fee, except as to salaries and railroad expenses. It is hoped that in Home Economics, especially, a large number of these schools may be held. During the past year there has been held, at the Agricultural College, the Annual Farmers' Short Course, continuing one week, with the registration of 115, and the annual Housekeepers' Short Course of five days, with a total registration of 215.

Colorado Farmers' Congress.—In connection with the above meetings was held the first meeting of the Colorado Farmers' Congress, to which there were 140 delegates representing sixteen organizations at this meeting. It is hoped that the next meeting of this Congress may show a large increase in the number of organizations represented by delegates, that this State organization may develop into the most important agricultural organizaion in the State, and that the week of its meeting at Fort Collins may become the most important event agriculturaly in the State in the minds of all people interested in agriculture.

Miscellaneous.—The activities of the College in Agricultural Extension for the past year have included the furnishing of speakers to special meetings such as those of granges, picnics, etc., the furnishing of judges for various fairs, carnivals and similar occasions, as well as the carrying on of a very considerable correspondence. It is recommended that the several departments of the College be requested at an early date to begin the preparation of suitable material for exhibit at the various fairs of the State next fall. It is believed that if suitable material be prepared so that transportation may not be too difficult nor expensive that the various fair associations will be glad to assist, that they will in fact bear the expense of these exhibits to their various fairs. The plan which your Superintendent would suggest is a modification of the plan used by the Ohio State College which is made the subject of a bulletin now in your possession.

Respectfully submitted,

C. H. HINMAN,

Superintendent of Extension.

REPORT OF THE FARM MANAGER.

To the President:

I submit herewith my report as Farm Manager for the current year up to and including September 30th. I am aware that this report should contain all data up to December 1st. Our data up to September 30th is now on the Secretary's books, but owing to the lack of sufficient clerical help, it has not been possible to get the books in shape beyond this date.

There has been considerable complaint in the past among our own people, and from others, that the college farm was a constant bill of expense. As no account had been kept of receipts and expenditures, the Board decided to appoint a Farm Manager. Accordingly in March, 1910, Professor Bainer was appointed Farm Manager and instructed to keep an accurate account of all labor and materials fur-

nished to other departments, as well as all labor and materials furnished outside the Institution. Professor Bainer immediately organized a system of daily accounting so that all work done or materials furnished were reported daily to his office. A summary was then made of these daily reports which was sent to the Secretary's office, and there entered upon a set of books kept in that office. In the system devised an account was kept not only with the various departments, but also, an accurate account of the various operations entering into the cost of producing crops on the fields. The effects of the system of daily reports were at once apparent. The men began to feel that the office knew what they were doing from day to day, and as a consequence they succeeded in accomplishing about one-third more than they had formerly been doing. If nothing else had been accomplished other than increased efficiency of the labor, the system would have justified itself.

The total received from all departments for man and horse labor and materials furnished is $13,141.52.

It will be noticed from these figures that the farm is doing a great deal of work and furnishing a large amount of material to other departments on the campus. This work must be done either by our own college force or by labor employed from the outside. As at present conducted, the farm stands ready to furnish this necessary labor and material. For doing all these things, however, a slightly larger force is required than would be necessary to simply conduct the ordinary farm operations, and, as a consequence, the apparent expense comes rather high, but when this work and materials are paid for by those who receive the benefit, the farm receives its proper credit. While not so designated, it is thus seen that we are really conducting a farm and labor department for the benefit of the entire institution. Such a department has its only excuse in existence in service rendered. That our force, as at present constituted, is highly efficient, has been attested on numerous occasions. The road expert sent here by the U. S. Government to superintend the installation of our experimental road, made the unqualified statement that he had never in all his experience of road building had a force which moved dirt faster or more efficiently than our farm force which did this work upon the experimental road. Our men become trained in making repairs and meeting other emergencies quickly, and we have a force always at hand, so that when emergency exists we can give prompt and efficient action.

One of the first duties which Professor Bainer imposed upon himself was the division of the farm into fields. A map was constructed showing the location and size of each of these fields. In our farm operations an accurate account has been kept of all of the items

of cost entering into the care of each of these fields as well as the returns therefrom.

Total Cost on Fields	$ 2,100.76
Total Returns From Fields	3,007.88

Labor charged to the fields and to the various departments was at the rate of 20 cents per hour, for man labor, and 12½c per hour for horse labor.

In addition to the accounts that we are now keeping, an account should be kept of the amount of water used in our irrigating operations. To keep such an account it would be necessary to have measuring weirs or meters to measure the water applied to the land. Our present data with the water data would give us the complete cost of operating land under our conditions. Many problems in Farm Management could be worked out from such data. We would be able to determine in a few years' time with considerable accuracy just how much labor, just how much water, and, indeed, all other factors required in computing the cost of the operation of land under our conditions. Owing to the fact that we are a State Institution, and that our men work only ten hours a day, and that we are doing a large amount of other work which frequently breaks into the continuity of the farm operations, this cost would be somewhat higher than what could be expected upon the average ranches. However, it would furnish a very accurate basis for comparison.

I recommend that the Farm Manager be empowered to adopt a rotation for the college farm, such rotation to be adopted after due consultation with the various departments interested. The object of the rotation being to keep up the fertility of the land and to give the highest service possible to the departments which have experimental or instructional use of the lands. Really the only excuse for the existence of the farm as a farm is the service it can render the college through its instructional work or the station through its experimental work. Rotations should therefore be devised in such a way that they will keep up the fertility of the land and furnish the animal husbandry, the horticultural, and other departments with the very best service consistent with their needs in instrucion and experiment.

All grain crops grown in the rotation should be of the best adapted sorts so that the seed thus produced could be sold for seeding purposes. Much of our land needs to be put into rotation in order to clean up obnoxious weeds such as wild oats as well as keep up the fertility.

I recommend that the Farm Manager be empowered to install the necessary weirs and meters required to measure the water applied to the farm lands. These meters and weirs to correspond to specifications ageed upon by the head of the Irrigation Department.

Respectfully submitted,

ALVIN KEYSER, Farm Manager.

Bulletin 151 JANUARY, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

RATION EXPERIMENT WITH LAMBS

1906-07, 1907-08.

SELF FEEDERS FOR HAY

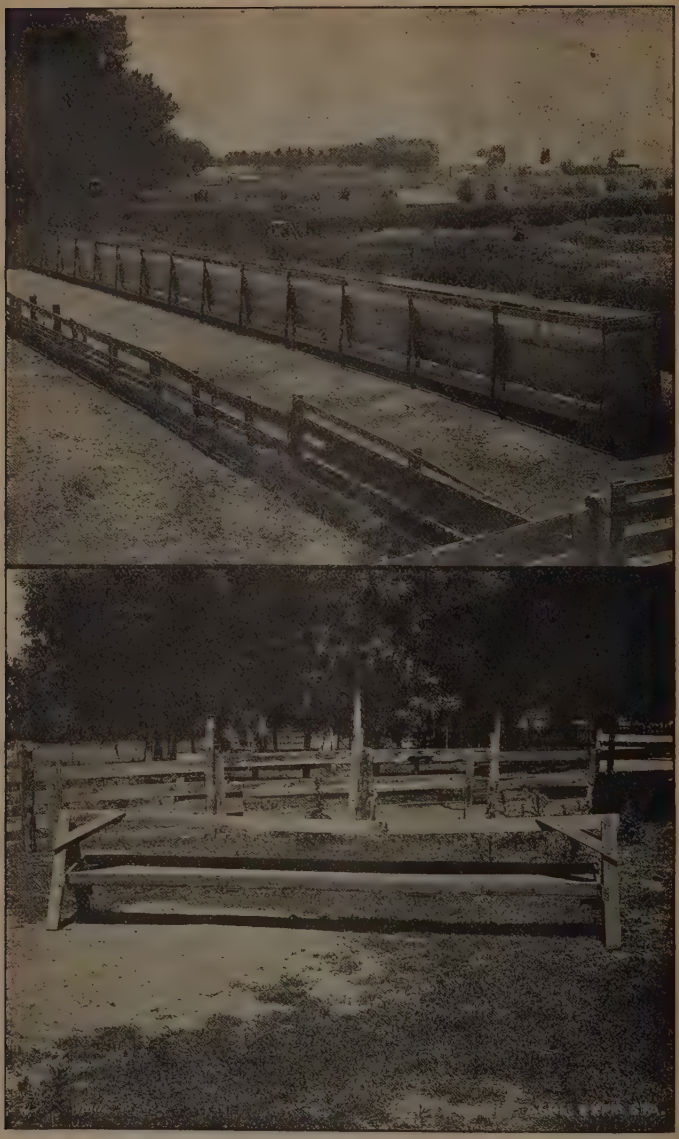
BY

W. L. CARLYLE

AND

G. E. MORTON

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1910



Upper—Self Feeders For Hay.
Lower—A Type of Grain Trough.

RATION EXPERIMENT WITH LAMBS.

1906 1907. 1907-1908.

W. L CARLYLE and G. E. MORTON.

INTRODUCTION

This bulletin covers two winters' work with lambs done under the direction of W. L. Carlyle. The first winter's work, on Cut Hay versus Whole Hay, was carried out by H. M. Cottrell, and the second winter's work on Cut Hay versus Whole Hay, and on Self Feeders for Hay compared with Old Style Hay Racks, was carried out by the writer, G. E. Morton.

CUT HAY VERSUS WHOLE HAY—ALFALFA—FIRST TRIAL

The Fort Collins district furnishes an excellent field for the study of the lamb feeding industry. Because of the large numbers fed, and the high ranking of the finished lambs on Eastern markets, feeders are unusually alert in their search for means of reducing the cost of production. One of the questions frequently put to live stock men of the College and Station has been concerning the value of cutting alfalfa hay into short lengths. There is considerable waste in feeding whole hay to sheep as they reject quite a large percentage of the stems. There is no doubt that cutting the hay causes sheep to eat it more closely, but the question of interest is whether enough saving is effected by the cutting to reimburse the feeder for the cost of cutting

The trial here reported was made with grade Shropshire lambs from the Idaho range. The lambs were fed whole hay and corn for a period of seven weeks, and were then put upon experiment, one lot being fed whole hay and the other fed hay run through an ordinary feed cutter, and cut to 1/8 of an inch in length.

TABLE I.

TOTAL WEIGHTS AND GAINS—SIX WEEKS

Dec. 1st, 1906, to Jan. 12th, 1907—125 Lambs in Each Lot

Lot No	Weight at Beginning (lbs.)	Weight at Close (lbs.)	Gain in Weight (lbs.)	Total Feed Consumed, (lbs.)		
				Corn	Alfalfa Hay	Oil Meal
A Whole Hay	12,635	14,256	1621	7785	24,592	140
B Cut Hay	12,533	13,948	*1505	7903	10,893	140

*Gain shown by final weight plus 90 lbs., weight of lamb which died.

The weights and gains made by the two lots, as shown in the table, are very closely alike. The amounts of corn and oil meal fed the two lots were also nearly equal. But the hay eaten by the lot fed whole hay was over double that eaten by the lot fed cut hay. Table II shows how this effects the feed required for 100 pounds of gain and the cost of gain. There was only one pound difference in the average gain per head made by the two lots of lambs in six weeks.

TABLE II.

FEED FOR GAIN AND COST OF GAIN—125 LAMBS IN EACH LOT

Lot No.	Ration	Average Gain Per Head, Six Weeks, lbs.	Pounds of Feed For 100 Pounds Gain			Cost of Feed For 100 lbs Gain*
			Corn	Hay		
A	Corn, Alfalfa Hay, Whole, on Ground	13	478	1511	8.6	$8.73
B	Corn, Alfalfa Hay, Cut, on Ground	12	525	724	9.3	7.61

*NOTE—Corn at 1 cent per lb., Alfalfa Hay at $5.00 per ton, Cut Hay at $6.00 per ton, Oil Meal at 2 cents per lb.

FEED FOR GAIN

The lot fed whole hay required 47 pounds less corn for 100 pounds gain than the lot fed cut hay, but ate 1511 pounds of hay for every hundred pounds gain, while the cut hay lot ate only 724 pounds of hay for each 100 pounds gain. This is a marked difference.

COST OF GAIN

The prices, from which the costs given in the above table were computed, are not the exact prices of the feeding stuffs at the time the experiment was carried on; but they are round numbers, and changing the prices of feed stuffs in this instance could not greatly affect the ratio between the figures for the two lots. This experiment shows a considerable saving by using cut hay, although the cost of feed for 100 pounds of gain in either case is so high as to be almost prohibitive. A partial explanation of this may be found in the fact that the fleeces of the lambs were trimmed preparatory to showing at the Western Stock Show, causing a shrinkage in the weight of the lambs during the fourth week. With Lot B this shrinkage amounted to a loss of 252 pounds for the week, or about 2 pounds per head. The most of this shrinkage was regained the following week, however, as shown by the gain of 529 pounds for that week, or over five pounds per head. So we cannot look for an explanation of the high cost in this shrinkage. But considering the feed given the whole hay lot, we find that they ate on an average 4.7 pounds of hay per head each day, an enormous amount. This would indicate very poor hay or an unnecessary waste of good hay, so that in either case, one would not be justified in reaching the conclusion that the economy shown by the table would ordinarily follow the use of

cut hay. In view of the unusually heavy consumption of whole hay, a series of experiments along the same line is necessary before a conclusion is warranted. The trial reported below is the second in a series bearing upon the same problem.

CUT HAY VERSUS WHOLE HAY, ALFALFA, SECOND TRIAL

In this trial, self feeders for hay were used, and if there be economy in the use of cut hay, it should appear under these conditions; for the self feeder should protect fine cut hay and leaves from staling and from being blown away by the wind even to a greater degree than they protect whole hay, with the following exception. If there are frequent wet snows, these serve to cause greater waste of cut hay than of whole hay when self feeders are used, because the cut hay dries out less readily than the whole, and so becomes less palatable.

In the following table, Lots I and II are the Lots to be compared:

TABLE A

TOTAL WEIGHTS AND GAINS—14 WEEKS

Nov. 23d, 1907, to Feb. 29, 1908—200 Lambs in Each Lot

	Lot	Weight at Beginning (lbs.)	Weight at Close (lbs.)	Gain in Weight (lbs.)	Total Feed Consumed, (lbs.)	
					Corn	Alfalfa Hay
Hay, Cut, in Self Feeder	I.....	11,675	19,330	7655	20,445	46,329
Hay, Whole, in Self Feeder	II.....	12,240	19,170	6930	20,595	41,615
Hay, Whole, on Ground	III...	11,813	18,555	6742	20,595	49 425

The amount of corn eaten by the two lots was practically equal. There is again a difference in the amount of hay eaten, but in the opposite directions, showing 4700 pounds of hay saved by the whole hay lot. This may be accounted for by too wide an opening in the self feeders where the lambs remove the hay, resulting in some waste of cut hay. The self feeders are in an experimental stage even for whole hay, and little is known concerning their construction for greatest economy with cut hay.

TABLE B

FEED FOR GAIN AND COST OF GAIN—200 LAMBS IN EACH LOT

Lot No.	Ration	Average Gain Per Head, 14 Weeks (lbs.)	Pounds Feed For 100 lbs. Gain		Cost of Feed For 100 lbs. Gain *
			Corn	Alfalfa Hay	
I.....	Corn, Alfalfa Hay, Cut, in Self Feeder..	38.3	267	605	$4.48
II....	Corn, Alfalfa Hay, Whole, in Self Feeder	34 7	297	601	4.47
III. ..	Corn, Alfalfa Hay, Whole, on Ground..	33.7	306	733	4.89

*NOTE—Corn at 1 cent per lb., Alfalfa Hay at $5.00 per ton, Cut Hay at $6.00 per ton.

ECONOMY

By the table above we see that the cut hay lot gained on the average of 3.6 pounds per head more than those fed whole hay. It required for 100 pounds of gain with the cut hay lot the same amount of hay and 30 pounds less of corn. This resulted in a cost of $4.48 and $4.47 for each hundred pounds gained by the two lots, estimating the cost of cutting hay at $1.00 per ton. The actual cost of cutting amounts to about 50 cents per ton, but counting interest on the capital invested in machinery and depreciation in value of machinery, the cost of cutting will approximate $1.00 per ton. Firms cutting hay for others charge even more than this.

This trial shows no economy in cutting a good quality of alfalfa hay. The hay used was well cured, first and second cutting hay. The only point in favor of the cut hay is that changes in the construction of the hay self feeders may result in a greater saving of the hay, and further trials will be made with this point in mind. In this trial the lambs were made to eat the whole hay about as closely as they do in a commercial feed lot, no unusual amount of stems being cleaned from their racks.

For the present the author feels justified in saying that so far as the experimental work with cut hay has gone at this Station, there is not sufficient evidence in favor of cutting hay to justify sheep feeders in putting in machinery for that purpose. The indications are that it does not pay to cut good alfalfa hay.

SELF FEEDERS FOR HAY.

The trial reported above also included a test of the value of self feeders. Lot II was fed whole hay in a self feeder and Lot III was fed whole hay in racks on the ground such as are in common use in many sections of the state.

From Table B, we find that the average gain of the two lots was 34.7 pounds and 33.7 pounds respectively; and the amount of corn required for 100 pounds gain was 297 pounds for Lot II and 306 pounds for Lot III. When we look at the amount of hay required for 100 pounds gain, we find quite a difference, 601 pounds being required by the self feeder lot, and 733 or over one-fifth more

hay required by those fed on the ground. This brings the cost of 100 pounds gain in live weight of the lambs fed on the ground up to $4.89 compared with $4.47 for the self feeder lot. With a higher price than $5.00 for hay the difference would be correspondingly greater.

The self feeder racks shown in the cut of the feed yards, cost $1.00 per running foot completed. They will accommodate about four lambs to the running foot, two on a side, as not so much space is needed at a self feeder as at the ordinary rack, not nearly all the lambs eating at one time. With hay at $5.00 per ton, these racks saved in the present instance 42 cents for each 100 pounds gain, or about 14 cents on each lamb. With four lambs to the running foot of rack this would be a saving of 56 cents against an initial cost for material of $1.00. With hay at $7.00 per ton, a saving of 18 cents per head was effected. This one experiment then indicates considerable advantage for the self feeder when whole hay is fed, as the racks would pay for themselves in two seasons or less. Another trial is contemplated.

SUMMARY.

Two trials of chopped hay do not settle the question of economy in cutting the hay, but the second trial with good hay, where undue waste was not allowed shows no economy. The lambs ate more hay and less corn when the hay was cut, but the cost of 100 pounds gain was practically the same whether the hay was cut or not, with $1.00 per ton charged for cutting.

One trial of self feeders for hay shows a considerable saving. With hay at $7.00 per ton, the self feeders costing $1.00 per running foot for materials, repaid their initial cost in one season, accommodating 6 lambs to the running foot.

LAMB FEEDING, 1907-1908

Bi-weekly Data, Lot 1. 200 Lambs in Lot. Ration: Corn, Alfalfa Hay, Cut, in Self Feeder

	Weight (lbs.)	Gain (lbs.)	Average Gain Per Head lbs.	Feed, lbs. Corn	Alfalfa Hay
Beginning.....	11675				
2nd Week.....	14270	2595	12.984	1895	
4th Week.....	15037	767	3.832	2800	
6th Week.....	15720	683	3.418	2800	
8th Week.....	16355	635	3.173	2800	
10th Week.....	17200	845	4.225	3150	
12th Week.....	18300	1100	5.500	3500	
14th Week.....	19330	1030	5.15	3500	
		7655	38.30	20445	46329

LAMB FEEDING, 1907-1908

Bi-weekly Data, Lot II. 200 Lambs in Lot. Ration: Corn, Alfalfa Hay, Whole, in Self Feeder

	Weight (lbs.)	Gain (lbs.)	Average Gain Per Head lbs.	Feed, lbs.	
				Corn	Alfalfa Hay
Beginning.....	12240				
2nd Week.....	14695	2455	12 278	2045	
4th Week.....	15340	645	3.223	2800	
6th Week.....	15835	495	2.478	2800	
8th Week.....	16195	360	1.80	2800	
10th Week.....	17010	815	4.078	3150	
12th Week.....	18030	1020	5.10	3500	
14th Week.....	19170	1140	5.70	3500	
		6930	34.67	20595	41615

LAMB FEEDING, 1907-1908

Bi-weekly Data, Lot III. 200 Lambs in Lot. Ration: Corn, Alfalfa Hay, Whole, on the Ground

	Weight (lbs.)	Gain (lbs.)	Average Gain Per Head lbs.	Feed, lbs.	
				Corn	Alfalfa Hay
Beginning.....	11813				
2nd Week.....	13935	2122	10.61	2045	
4th Week.....	14715	780	3.90	2800	
6th Week.....	15395	680	3.40	2800	
8th Week.....	15605	210	1.05	2800	
10th Week.....	16195	590	2.95	3150	
12th Week	17140	945	4.723	3500	
14th Week.....	18555	1415	7.078	3500	
		6742	33.73	20595	49425

Note.—It will be noticed that the lambs made a large fill the first two weeks. This was in spite of the fact that the experiment was not begun until six days after the lambs were unloaded, the lambs being given all the hay they would eat during this time.

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The Agricultural Experiment Station

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TWO COMMON ORCHARD MITES

THE BROWN MITE. THE RED SPIDER

BY

GEORGE P. WELDON

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TWO COMMON ORCHARD MITES

THE BROWN MITE. THE RED SPIDER

By GEORGE P. WELDON

The dry climate of Colorado favors the multiplication of mites, among the more common and troublesome of which are the two species treated in this bulletin. Throughout the year these two species have been found quite generally distributed in the orchard sections of the Western Slope, and in some localities their injury to fruit trees was quite severe. Very often both species are found on the same tree, and no little confusion exists among the orchardists in separating one from the other.

Because of the prevalence and severity of these pests it was thought best to carry on some experiments to determine how they may best be controlled. The results of these experiments, along with a general discussion of the life histories of the two species of mites, are given in this bulletin.

The mites are not true insects, having 8 legs when adult. They are classified as an order of the Arachnida, to which class the spiders belong.

THE BROWN MITE (*Bryobia pratensis* Garman) Plate I, Fig. 1.

Life History

There are three distinct stages in the life cycle of the brown mite. Beginning with the egg, a short account of each stage follows:

Most orchardists have seen the tiny red, globular eggs on fruit trees during the winter months, and are aware that they are the eggs of the brown mite. The winter is spent principally in the egg stage in Colorado. The over-winter eggs are deposited before the end of the summer season. This year practically no living mites could be found after the first of August, at Grand Junction or Delta, the eggs having been deposited previous to that date. On August 16, an occasional specimen of this mite can be found, but they are very rare and no more damage need be expected of them this season. The eggs are usually deposited on the trunk and limbs of trees, the crotches being favorite places. (See Fig. 7.) Often the bark is covered several layers deep with these eggs. By rubbing one's finger over the egg masses and crushing them, the bark of the tree may be made to assume almost a blood red color. We have found these eggs more numerous on pear, cherry, plum, prune, and almond than on any other orchard trees, the degree of infestation corresponding to the order in which the trees are named. Shortly after the warm weather of spring comes on, the tiny little bright red, six-legged mites may be seen crawling over the leaves and branches. By the first of May they were abundant the past

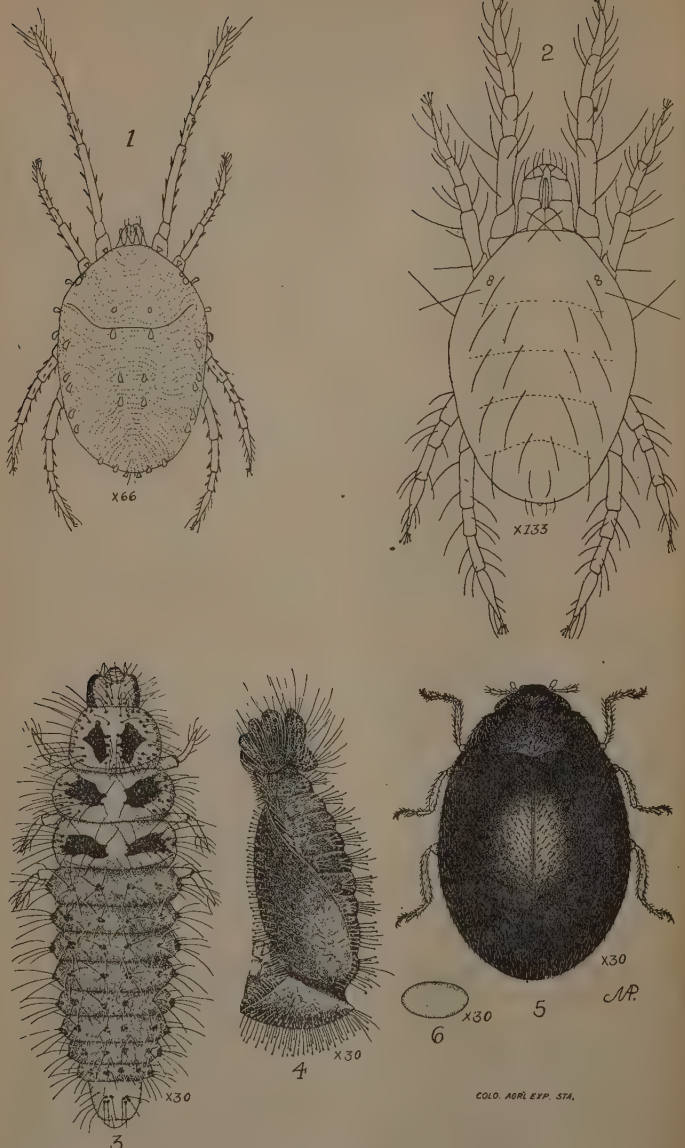

Plate I.—Fig. 1, Brown Mite (*Bryobia pratensis;*) 2, Red Spider (*Tetranychus bimaculatus;*) 3, 4, and 6, larvæ, pupa, adult and egg of (*Scymnus punctum.*) Figure 1, enlarged 66 times; 2, 133 times; 4, 5 and 6, 30 times. Original, Miss M. A. Palmer, delineator.

season at Delta, Colorado. Their color remains red until after they moult for the first time, when they are a brownish, or often an olive green color. After this moult they have 8 legs, instead of 6, which remain with them throughout life. The adult (Plate I, Fig. 1) is brown in color, with the exception of the legs and head, which have a reddish hue. The front pair of legs is very long, and are constantly kept in motion when the mites are feeding, as though they used them to feel their way about on the surface of the leaves. Throughout the months of May, June, and July adult mites are depositing eggs, which may constantly be found on infested trees. If the infestation is severe, not only are their eggs deposited on the bark, but very often a few are deposited on the leaves. They have been noticed principally upon the upper surface, and in the furrow of the mid-rib.

While it is very hard to determine whether or not there is a definite number of broods of this species of mite, observations the past season strongly indicate that there are but three broods.

Nature and Appearance of Injury.—The direct injury from brown mite is confined principally to the foliage. They have been observed feeding upon fruit, and not infrequently have we seen masses of them collected upon the stems where they appeared to be feeding. It is probable that the stems are used mostly as a moulting place. The epidermis of a leaf is pierced by their mandibles and the sap sucked from within. The first sign of infestation of a tree is the pale color of the leaves, not unlike that caused by leaf hoppers; when not abundant there may be only a few leaves affected. They generally attack the lower leaves first, and unless conditions are favorable to their increase, they may confine themselves largely to the water sprouts and tender twigs at the crotch of the tree. When multiplication is uninterrupted, they may cover the foliage of an entire tree, causing it to turn yellow and drop prematurely, thereby materially weakening the vitality of the tree. Little black specks, the droppings of the mites, render the fruit and foliage unsightly, and while there may be no serious consequences from this source, it probably does sometimes interfere with the looks of a fancy pack of early fruit. Often the fruit of a badly infested tree is small and does not mature properly.

Trees and Plants Infested.—The brown mite does not confine its attack to trees, for it was first described as a clover pest. Neither does it confine its attack to orchard trees, for shade trees have been reported infested by them. During our observations of this mite we have not found it on any of our shade trees. Much has been written about it as a household pest, but it seldom, if ever, becomes of any serious consequence in Colorado, where it winters mostly in the egg stage. In the warmer sections of the United States it is said to hibernate as an adult, often migrating into the houses in

the fall, where it may trouble the house-wife. During the present season they have been found on apple, plum, prune, cherry, pear, peach and almond in abundance. Probably less were seen on peach than any other of these trees. Only in one section were they observed to be of any serious consequence on peach. So common are they on all other kinds of trees mentioned that it would hardly be safe to say that they are more liable to attack one than another. An infested apricot, or quince tree has not been observed.

Remedies

The following experiments were conducted the past summer to determine which of the insecticides used would best control this pest, the applications being made as a spray, except No. 6:

May 4 and 5, Experiment No. 1.—Sulphate of nicotine, 8 ounces to 50 gallons of water.

May 4 and 5, Experiment No. 2.—Nico-Fume, 9 ounces to 50 gallons of water.

May 4 and 5, Experiment No. 3.—Nico-Fume, 6½ ounces to 50 gallons of water.

May 4 and 5, Experiment No. 4.—Black-leaf, 1 part to 70 parts of water.

June 4, Experiment No. 5.—Flowers of sulfur, 1 pound to 3 gallons of water.

June 4, Experiment No. 6.—Flowers of sulfur as a dust spray.

July 23, Experiment No. 7.—Flowers of sulfur, 65 pounds to 200 gallons of water, and 2 pounds of whale oil soap.

July 27, Experiment No. 8.—Same spray used as in No. 7.

Experiments 1 to 6 inclusive, were conducted by myself. No. 7 was conducted as recommended by me, and No. 8 under my supervision.

Nos. 1 to 6 were in the orchard of Mr. W. E. Obert at Delta, No. 7 in the orchard of Mr. McCarry at Grand Junction, and No. 8 in the orchard of Mr. C. D. Gehman at Grand Junction. Thanks are due these gentlemen for their assistance in the work.

The Sulphate of Nicotine and Nico-Fume are tobacco preparations manufactured by the Kentucky Tobacco Product Co., at Louisville. The Black-leaf is also a tobacco preparation manufactured by the same company. All the tobacco sprays were found to be effective in killing the mites touched by them, but apparently had no effect upon the eggs. An examination of trees 24 hours after spraying showed that many of the adult mites had not been killed. It is next to impossible to do a thorough enough job with any spray which will only kill the mites, to sufficiently hold them in check so that they will not damage the trees, as they hide in cracks of the bark, under bud scales, and in so many other places where it is impossible to reach them. A later examination of the

trees showed that the eggs were hatching in abundance, and that the adult mites were also abundant. Any spray that will not kill the eggs, and which will not adhere to the foliage until eggs hatch, is not a practical summer spray for brown mite. If it were possible to do a thorough enough job to kill all mites when the spray is applied and then make a second application later when all the eggs are hatched, that would be effective. Owing to the fact that it is practically impossible to kill all of both eggs and mites, and that the time of hatching of the eggs seems uncertain, the best that could be expected of tobacco sprays would be to keep the mites in check by repeated applications throughout the season. In the use of sulfur the experiments indicate that we have an absolute remedy for this pest.

In experiments Nos. 5 and 6 four small, badly infested cherry trees were treated, two sprayed with a compressed air hand pump, and two dusted with a bee smoker. It was found that by using a small amount of soap in the water sulfur would mix nicely, so that it could be applied as a liquid spray. successfully for applying the sulfur in the dry form. The best time to apply the sulfur in the dry form would be in the early morning, or late in the evening, when the dampness would cause it to adhere to the foliage. In experiment 6, sulfur was applied as a dust spray, and enough was used so that every leaf received a coating. An examination of trees was made June 7, and to my surprise, not a single adult mite could be seen; there were, however, many of the newly hatched ones. An examination of these trees again June 9 showed the same conditions. On this date a very careful examination was made of egg masses on check and treated trees. The egg masses (Fig. 7) are favorite places for the mites to moult, and along with those that are depositing eggs there are always many to be found there in abundance. Twenty-five separate egg masses on sprayed trees were examined with a hand lens and not a single adult mite was found. Every

Fig. 7 COLO. AGR. EXP. STA

Figure 7, twig with a large cluster of eggs of Brown Mite. Original, Miss M. A. Palmer, delineator.

egg mass examined on check trees in same row had from one to a great many mites crawling about over it. The foliage of sprayed trees recovered its normal green color, and remained so throughout the season, standing out in beautiful contrast to that of the untreated trees, many of the leaves of which turned yellow early in the season. Not only was there a difference in the foliage, but the fruit also showed a marked difference, that from check trees being small and worthless, while that from treated trees matured well and was good.

Experiment No. 7 showed just as conclusive results. The 300 pear trees in this experiment began to pick up immediately after spraying, and an improvement in the fruit was soon apparent. The only trouble in this orchard was that the spraying was neglected until too late, as much damage had already been done. An examination a few days after the spraying showed that treated trees were free from mites, while some plum trees in the orchard, which were left untreated, still had many of the mites on the foliage. As the infestation of mites on the pear trees was serious, it is probable that the spray paid for itself, even though it was late before the applicaton was made. Spraying in this experiment was done with a gasoline power outfit. Previous to the time of spraying this orchard with sulphur, a Black-leaf spray was used with very little success.

In experiment No. 8, twelve cherry and two plum trees were used. The mites were completely exterminated from these trees. One cherry tree was left as a check, and an examination of the trees ten days after spraying failed to reveal the presence of any mites on the treated trees, while on the one check there were still many of them.

I feel that the results of these four experiments with sulphur sprays are conclusive, and that it is perfectly safe to recommend a spray of flowers of sulphur and water for brown mite. While 65 pounds to 200 gallons of water were used in these experiments, it is probable that 50 pounds would be enough. A small amount of soap must be used so that the sulphur will mix with the water. If soap is not used the sulphur will remain on the surface and no amount of agitation will mix it. Two pounds of soap to 200 gallons of water is plenty, and probably less will answer the purpose.

Prof. Gillette has found that a soluble oil spray is more effective in killing the eggs than are the tobacco sprays. In the case of the mites themselves this was reversed, and tobacco prepartions were the more effective. While soluble oil might be successfully used as a dormant spray, it is not a reliable remedy where water is strongly alkaline, and if such water is used a thorough mixture cannot be maintained with any of the different brands of soluble oil that the writer has tried to use. Because of this fact none of

the soluble oil sprays were used in the experiments.

It has been determined that lime and sulphur, applied when trees are dormant, will kill mites. Prof. Gillette has experimented with the lime and sulphur sprays upon the eggs of brown mite and has concluded that they are of no value as far as the destruction of the eggs is concerned. Their efficiency seems to depend upon their power to kill the young mites after they hatch from the eggs. Lime and sulphur is very adhesive, and the sulphides of lime will remain on a tree for months after the spraying has been done. Especially is this true in Colorado, where the rainfall is not great.

SUMMARY.

1. The brown mite has been quite a serious pest in Colorado the past season, doing considerable injury to orchard trees, as well as interfering with the maturity of the fruit.

2. The over-winter eggs are deposited in late summer, most of them before the first of August this season; they remain on the trees throughout the winter and hatch shortly after the leaves come out in the spring.

3. Apple, peach, plum, cherry, pear, and almond trees were found infested. Apricot and quince do not seem to be troubled.

4. Mites feed principally upon the foliage where their presence may be detected by the pallid leaves, and the tiny black spots of excreta.

5. Flowers of sulphur, one pound to three gallons of water, and enough soap so that the sulphur will mix with water, is a perfectly effective remedy when used as a summer spray.

6. Tobacco preparations will kill the mites, but not the eggs, and are only effective when repeated applications are made. Oil sprays seem to penetrate the eggs, and destroy them better than the tobacco extracts, but are unsafe to use with water strongly impregnated with alkali.

7. Trees may be treated while dormant with lime and sulphur. This spray has no effect upon the eggs, but probably kills the young mites as they hatch.

THE RED SPIDER (*Tetranychus bimaculatus* Harvey) Plate I, Fig. 2.

Although there are a number of different species of red spiders, or spinning mites, we have found only one species infesting orchard trees in Western Colorado. While in most localities it was probably not responsible for as much damage as the brown mite, still it was of somewhat serious consequence, and is a pest to be watched, and combatted if necessary, to keep it from becoming injurious the coming season.

Life History

Both species of mites treated in this bulletin belong to the same family, but differ from each other in many important respects. The eggs of the red spider are deposited chiefly on the under surface of leaves. An examination of infested trees will reveal the presence of these tiny transparent eggs, resembling minute dew-drops attached to the surface of a leaf, or interwoven among the silvery threads which the mites are capable of spinning. As is the case with the brown mite, these have only six legs when first hatched, the fourth pair developing later. The adult (Fig. 2) is somewhat smaller than the adult brown mite and the fore pair

of legs are much shorter, as is shown in the figures. When the mites are seen with the aid of a glass, upon the surface of a leaf, the legs appear much shorter than they do in the drawing, for the reason that they are not extended to their full length while the mites are feeding, or while at rest, while those of the brown mite are nearly always extended to their full length. A glance through any ordinary hand lens is all that is necessary to be able to distinguish the brown mite from the red spider, because of this characteristic. When first hatched this species of red spider is light green, with small dark colored spots on the back. Later the color may change from a light green to a deep brown, or a bright red. Owing to the variability of color this character cannot be depended upon at all in the identification of the species. The spots also vary in size and placing on different individuals. Generation after generation of the mites appear during the summer months, and at all times of the season there may be found eggs, and all other stages of the mites upon the leaves.

The winter is spent in the ground, and here we have an important difference in the life history of the two species treated in this bulletin. On August 9th, myriads of red mites were found in the ground at the crowns of trees upon which they had been feeding. At this time they were all red in color. Although most of them occurred close to the trunks of trees, some were found at a distance of 10 feet away, where they had crawled beneath clods of soil undoubtedly to remain over winter. It is probable that out of the large numbers that leave the foliage and enter hibernation quarters only a very few survive the winter. In the early spring, when the foliage begins to grow, these few crawl out of their winter quarters, ascend the trunks of trees and deposit their eggs for the perpetuation of the species. On last April 7th a number of these mites were found trapped in a "Tree Tanglefoot" band, which had been applied to the trunk of an apple tree to catch the migrating woolly aphids which wintered in the ground.

Nature and Appearance of Their Injury.—The injury from this species is similar to that of the brown mite. The leaves of an infested tree are often yellow in spots, which present a blister-like appearance. This condition has not been observed with brown mite injury, and is due to the red spiders spinning their webs over certain small areas of the leaves, and feeding within those areas. The webs are always found on leaves injured by red spider, and when the orchardist finds these webs he can rest assured that he has red spider to contend with, as the brown mite does not have the power of spinning a web.

Trees and Plants Infested.—In every case, mite injury to shade trees observed the past season, was due to this species of red spider, and not to the brown mite. It has been observed on the same fruit

trees as the latter, but in addition it has been commonly found on poplar, ash, and walnut, as well as a great variety of herbaceous plants. In many cases small fruits have been damaged severely. Raspberry, currant, and gooseberry bushes have probably been the greatest sufferers among the small fruits. The injury in this case is the same as to the trees. The leaves are sapped of their vitality, turn yellow and drop early. The fruit is small, often not maturing sufficiently to be salable.

Remedies

Last season the writer tried to kill this pest on some rose bushes at Delta, Colorado, by using a spray of "Black Leaf Extract," using 1 part of the black-leaf to 65 parts of water. A small compressed air spray pump was used, and as thorough an application as it was possible to make was given the bushes. At first it appeared as though the tobacco was thoroughly effective, but an examination of the bushes next day showed that while a great many of the mites had been killed many live ones were still crawling over the leaves, and the eggs did not seem to be affected in the least. In about a week's time the bush was sprayed again, and finally was sprayed a third time by the owner, and even then it seemed impossible to kill enough of the pests so that they would not damage the bushes.

Recently the sulphur spray (sulphur 1 pound, water 3 gallons) recommended for the brown mite, was tried on three small peach trees at Palisade, and the results were highly gratifying. Trees were sprayed on August 12, and on August 17 an examination showed the leaves to be entirely free from red spider, while untreated trees close by, were just as badly infested as upon the day of spraying.

Early in August, Mr. R. B. Cassells, who has an orchard on Fruit Ridge, Grand Junction, complained of a few of his plum trees being infested with the spiders. A sulphur spray was recommended and applied, and again the results were perfect. The trees not only recovered somewhat of their normal color, but the fruit also improved rapidly.

The only objection that might arise to a spray of sulphur so late in the season, would be the odor it would give to the fruit of sprayed trees. It is not probable, however, that any trouble would arise from this source, except possibly in the case of peaches, where the fuzz would cause the sulphur to adhere. Of course, trees should be sprayed as soon as the injury begins, and should not be allowed to remain unsprayed until the end of the season, when practically all of the injury has been done to them. The use of a sulphur spray upon small fruit bushes cannot be too strongly recommended, as these are so often materially injured by red spiders.

Natural Enemies

The principal enemies of the red spider, found during the season's observations, were the lace-winged flies, and a small black species of lady-bird beetle, which Prof. Gillette has determined for me as *Scymnus punctum*.. (See Figs. 3, 4, 5 and 6 of Plate I.)

Several times during the season lace-winged fly larvae have been observed on leaves infested with mites, and no doubt they were feeding upon them. The little lady-bird was found quite abundant on infested peach trees in one orchard at Palisade. It is a tiny black beetle, so small that the orchardist might not become aware of its presence in an orchard even though it should occur in abundance. The larvae are also of a blackish color, and can be readily seen on the leaves when they are feeding upon the mites. The drawings of this lady-bird were made from specimens collected by Prof. C. P. Gillette, at Greeley and Fort Collins, Colorado. Prof. Gillette found them specially common on elm and plum leaves, where they were feeding upon red spiders and working for the most part beneath the webs. He has briefly described the different stages of this beetle as follows:

"The eggs are very small, pale yellow objects, oval in shape, and are deposited singly upon their sides. They are almost too small to be seen by the unaided eye, as they measure barely one-third of a millimeter (one-seventy-fifth of an inch) in length.

"The grubs or larvae are dusky to blackish in color, rather hairy, the hairs being simple and arising in clusters from minute tubercles.

"The pupa is uniform blackish in color and is covered with short golden hairs, most of which terminate in a knob.

"The adult beetles are dull black, with the tibiae and tarsi (lower portion of the legs) pale yellow, and the dorsal surface is set with short golden hairs that are not capitate but pointed; the general form is almost circular, and the length about one and one-third millimeters (one-twentieth of an inch)."

SUMMARY

1. Only one species of red spider has been found injuring orchard trees in Western Colorado.

2. Eggs are deposited in the spring by mites that have hibernated over winter in the soil, or beneath rubbish of any kind in the orchard. Hibernation began as early as August 9th this season, and myriads of the little red pests were found in the ground at Palisade, on that date.

3. Many fruit and shade trees are attacked by the mites. Small fruits are often severly injured Herbaceous plants of all kinds seem to be subject to attack. When fruit trees are badly infested the fruit is usually small and does not mature properly.

4. A sulphur spray, the same as is recommended for the brown mite, is probably better than anything else that could be used during the summer months.

5. The natural enemies of the red spider that were noticed during the season were the lace-winged flies, and a minute black species of lady-bird beetle (*Seymnus punctum.*)

Credit is heartily accorded Miss M. A. Palmer, who made all the drawings for this bulletin.

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

AGRICULTURAL PRODUCTS SHIPPED INTO COLORADO IN 1909

BY

H. M. COTTRELL

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INTRODUCTORY

Colorado has not provided means of obtaining statistical information which enables the people and commercial interests of the State to take account of their progress and thus to determine the character of their growth or the conditions which may need improving. In the absence of authentic data of that kind Professor H. M. Cottrell was authorized to obtain information from all sources possible as to the amount of produce actually shipped into the State and especially of a character the state could produce. While the information thus obtained cannot be considered as exact, yet as the sources of information are in close touch with the products in question, the estimates are believed to be close to actual facts. In some cases they may be considered as exact. The railroads and commission men, and in fact all classes have been free to aid, in many cases have opened their books to inspection and have given the advantage of their expert knowledge. The statements therefore represent what is, no doubt, the best summary of such knowledge that is available or has ever been made.

From the standpoint of the State it indicates the large demand for agricultural products that is not met by the growers of this State. This shows only the production shipped into the State, and does not show the amount shipped out of the State. In some cases this is considerable. Thus several times the value of flour is shipped out of the State that is shipped in. Our fruit growers ship out several million dollars worth of fruit annually. Several million dollars worth of potatoes are shipped out annually and shipments of hay and live stock amount to many million dollars each year.

The facts, however, deserve careful consideration, and give a basis for lines of intelligent development.

L. G. CARPENTER, Director.

AGRICULTURAL PRODUCTS SHIPPED INTO COLORADO IN 1909

BY H. M. COTTRELL

According to the most accurate data that could be secured by the Farmers' Institute Department of the Colorado Agricultural College, the following agricultural products were shipped into Colorado in 1909 from other states:

	Estimated Value
Fat Animals for Slaughter	$3,568,380
Fresh Meat	1,094,080
Cured Meats, Lard and Butterine	2,546,680
Canned Meats	1,200,000
Dairy Products	3,986,000
Poultry and Eggs	4,000,000
Wheat	3,750,000
Flour	1,500,000
Millstuffs and Corn Meal	860,000
Corn	2,530,000
Oats, Rye and Barley	310,000
Breakfast Foods and Food Cereals	1,122,000
Crackers, Wafers and Fancy Biscuits	350,000
Broom Corn	96,000
Hay	1,450,000
Field Seeds	240,000
Fresh Fruits, Melons and Vegetables	1,993,000
Canned Fruit and Vegetables	1,345,000
Dried Fruits	500,000
Pickles, Catsup and Pork and Beans	175,000
Total	$32,616,140

FAT ANIMALS SHIPPED IN FOR SLAUGHTER:		
Cattle	$1,297,872	
Hogs	2,245,288	
Calves	25,220	$3,568,380
MEAT AND MEAT PRODUCTS:		
Fresh Meat:		
Beef	$472,680	
Pork	591,600	
Veal	10,800	
Mutton	19,000	$1,094,080
Smoked Meats	$918,000	
Lard	520,000	
Lard Compounds	93,000	
Butterine	930,000	
Mince Meat	15,680	
Extract of Beef	70,000	$2,546,680
Canned Meats:		
Beef, Veal, Bacon, Ham, Chicken, etc		$1,200,000
	Total	$8,409,140

PORK:

Of the 241,570 hogs received at the Denver Stock Yards in 1909, 61,947, or a fraction over one-fourth, were grown in Colorado.

The value of hogs, pork and pork products shipped into Colorado in 1909 were:

Hogs	$2,245,288
Fresh Pork	591,600
Smoked Meats	918,000
Lard	520,000
Total	$4,274,888

Experts estimated that the value of the pork and pork products shipped from the corn belt into the Rocky Mountain and northwestern territory, of which Denver is the gateway, amounts annually to sixteen million dollars.

The three cracker factories of Denver used in 1909 as much lard as was furnished by all the Colorado hogs slaughtered in Denver. Yet every tillable section of Colorado is adapted to the cheap production of pork of the best quality.

Barley fed pork is the highest priced pork in the world, on account of its superior flavor. The irrigated sections of Colorado yield barley at a less cost per acre than the cost of growing corn in Iowa and Illinois, and the production of pork per acre from irrigated barley is greater than that of pork from corn in the corn belt.

The right strains of barley give profitable yields under dry land farming both on the plains and at high altitudes.

Milo is the surest grain crop for dry land farming on the Plains, and produces a choice quality of pork. The Plains farmers alone could produce all the pork and pork products needed in Colorado and adjoining states if they would make a specialty of pork raising, fattening with Milo.

Field peas as grown in the San Luis Valley make a better flavored pork than either corn or barley, and hogs in the San Luis Valley can be fattened on peas at a cost of one and one half cents per pound for the gain in live weight. There are three million acres in the San Luis Valley adapted to pea growing and a much larger area at high altitudes in other sections of Colorado.

Colorado should not only supply all the pork and pork products needed in the State, but should furnish the high priced, choicest pork, and pork products to the rest of the United States. The State needs 50,000 farmers who are expert swine growers and feeders. The majority of Colorado farmers have failed to make hogs profitable because they have neglected the growing pigs through the summer.

Beef.—Colorado beef cattle are better bred than those of most of the range states. The native grasses are not excelled for making growth on young stock and for putting flesh on older cattle. The meat produced from the grass and from the hay made from native grasses is of exceptionally choice flavor. The Colorado Experiment Station and private feeders have demonstrated that our grains, alfalfa, and roots produce, economically, beef of superior flavor with light waste in slaughtering and in cooking.

Fresh beef and veal are shipped weekly from the corn belt into most Colorado towns, and fat cattle were shipped, in 1909, from other states into Colorado, as follows:

	Cattle	Calves
Nebraska	3,778	716
Wyoming	10,299	1,118
Kansas	1,478	402
Utah	5,177	70
Idaho	3,823	151
Nevada	795	19
Oregon	723	46
Montana	343	...
California	623	...
Total	27,039	2,522

If Colorado cattle growers appreciated the value of our feeds, and would make a business of finishing their stock before marketing, we could not only supply our own needs for beef and veal, but on account of the flavor of meats made from Colorado feeds could create a widespread trade outside the state.

Butterine.—There has been such a scarcity of butter in the state and the prices have been so high that during the past year there has been an abnormal increase in the use of butterine, experts estimating that an average of over 10,000 pounds per day is used in Colorado, and that there will be a large increase over this during the coming year. Government officials state that over four times the number of people are selling butterine in Colorado than were in the business eighteen months ago.

Fresh Meats.—Fresh meat is regularly shipped from Omaha to

Denver, and also in carload lots as far west as Grand Junction. It is distributed throughout the mountain sections of Colorado, as well as in the eastern part of the state.

DAIRY PRODUCTS.

Butter and Cream	$3,000,000
Cheese	500,000
Condensed Milk	400,000
Malted Milk	86,000
Total	$3,986,000
Butterine, which is used to take the place of butter	930,000
Total	$4,916,000

There are approximately 160,000 milch cows in Colorado. Many are cows selected from the range and are poorly handled and milked through the summer, producing annually only from $20 to $50 a cow A number of well selected cows are kept in or near towns, and are fed, producing annually from $50 to $150 a cow. The average annual production is probably not over $40 a cow, or a total yearly production for the state, from dairy products, of $6,400,000. If these estimates are correct, Colorado farmers are supplying about 56 per cent. of the dairy products and substitutes for dairy products consumed in the state.

Butter and Cream.—A large amount of butter is shipped into Colorado from Kansas and Nebraska .and the larger proportion of the cream churned in the large factories in Denver, Colorado Springs, and Pueblo is shipped in from Kansas and Nebraska. One concern alone in Denver churned, in 1909, over three million pounds of butter, a large per cent. of it from Nebraska cream.

Some of the largest handlers of dairy products in the state estimate that in 1909 an average of over 30,000 pounds of butter were shipped daily into Colorado either as butter or in cream that was churned after arrival. Butter made from Kansas and Nebraska cream is used in Mountain sections of Colorado 450 miles distant from Denver.

Cheese.—The quantity of cheese made in Colorado is so small that it is seldom found in most of the towns of the state. Most of the cheese eaten in the state comes from New York.

Condensed Milk.—The one condensed milk factory in Colorado is situated at Fort Lupton. It has a good trade, puts up a good product, and pays a high price to the farmer for milk.

During 1909 there was a general shortage of milk and cream in most of the towns of the state, and city families were forced to use condensed milk. Many thousand farm families also used condensed milk.

The use in Colorado of condensed milk has been increasing rapidly every year for several years. Wholesale houses report that in 1909 they had a demand for double the quantity of condensed milk that they sold, but they could not secure it from the manufacturers.

More than the usual amount was shipped into the state from the east and several carloads from the Pacific Coast.

The fresh milk from 8,000 average Colorado cows would have been required to produce the condensed milk that was shipped into Colorado in 1909, and the milk from 16,000 cows to fully supply the demand in the state for this food.

Every section of Colorado offers favorable conditions for dairying. The irrigated sections of Colorado offer ideal conditions in every respect:—feed, climate, water, and good markets.

The mountain parks and valleys of Colorado furnish almost the same dairy conditions as the mountain dairy districts of New York, with the advantages of richer feeds and a dry climate. These parks and valleys cover a large area, a single one—the San Luis Valley—having a tillable acreage as great as the entire state of Connecticut.

Good, early cut alfalfa hay will produce as much milk as an equal weight of bran, one of the chief eastern dairy feeds. Alfalfa hay can be produced and fed to dairy cows on the average Colorado farm for $3 to $5 a ton. Bran in eastern dairy sections costs $20 and upwards a ton. A ton of alfalfa hay contains about as much milk producing material as four tons of timothy hay.

Alfalfa grows well in most sections of Colorado up to an altitude of 8,000 feet From 6,500 to 8,000 feet field peas give high yields. Both the hay and grain from this crop are good milk producing feeds, pea hay ranking next to alfalfa for this purpose.

At high altitudes red and alsike clover yield large crops, the latter doing well up to an altitude of 9,500 feet. Both are rich milk producing feeds. The nutritious character of Colorado forage crops makes little grain necessary.

To the many new settlers who are starting dry land farming on the plains of eastern Colorado, dairying offers a sure income. In the past thirty-three years there has never been a year so dry but that a sufficient quantity of feed could have been raised, together with the native grasses, to produce a good yield of milk.

The native grasses are good milk producing feeds, summer and winter. The Sorghums, Milo and Kafir-corn are good drought resisting crops, and in a dry year wheat, oats and beardless barley cut just as they are filling make excellent dairy feeds and often a profitable crop can be secured from these grains by making them into hay, when if left to mature the season would be too dry for them to make marketable grain.

The mild climate of Colorado makes the necessary expense low for shelter. For twenty years the average temperature at Fort Collins for January—the coldest month—has been twenty-six degrees, and for July, the warmest month, sixty-eight degrees, with a few days each year of either extreme heat or cold.

The dry bracing air and high altitude give vitality and health to the cows. Dr. George H. Glover reports that only one-half of one

per cent. of the native cattle of Colorado show any trace of tuberculosis, and less than two per cent. of the cows in Colorado cities, where they are closely confined.

The pure air of the high altitude and the intense sunshine—an average of three hundred and twenty days of sunshine each year—make the air much freer from germs which taint milk than the air in low, humid states. For this reason it is much easier and costs less to keep milk and cream sweet in Colorado than it does in states East.

POULTRY AND EGGS.

Eggs	$2,000,000
Poultry	$2,000,000
Total	$4,000,000

Fifty car loads of eggs were taken in a single month from cold storage plants in the East and brought to Denver. Poultry is shipped direct from Omaha to Glenwood Springs and other mountain towns. Even in mountain towns as distant as Telluride, poultry and eggs are shipped direct from Wichita, Kansas. In July, 1909, the hotels in Durango were obliged to furnish their guests Kansas eggs because Colorado eggs could not be secured.

During the past Fall and Winter an average of $1,000 per week has been sent out of Fort Collins for Kansas and Nebraska eggs, and most towns in Colorado have sent out proportionate amounts. One Bank in Denver reports that its customers, alone, send an average of $10,000 a week to Nebraska for poultry.

An investigation made in Pueblo by the Business Mens' Association showed that more money was being sent out of that city to other states for poultry and eggs and butter than was being spent in the city by the 4,000 employes of the great ten million dollar steel plant of the Colorado Fuel & Iron Company, and by the employes of the smelters. Denver dealers handle an average of over $3,000 worth of eggs, daily, and a large part of this is brought from other states.

Two years ago the Farmers' Institute Department of the Colorado Agricultural College made an investigation of egg production in Colorado, having the assistance of a poultry expert from the East as well as Colorado poultry experts.

It was found that in both small and large flocks and in various parts of the state, poultrymen who thoroughly understood the managing of the business under Colorado conditions of feed and climate were making an average of $2.00 a hen a year above the cost of feed. Poultrymen around New York, Boston, and Philadelphia were making but half this amount.

At the same time most of the Colorado farmers, who were consulted, reported that their hens were "eating their heads off" and that keeping poultry was a loss to them.

Colorado needs, at the present time, at least 5,000 men who are

experts in egg production, and these men can make much more than they are making in eastern states.

Our average of 320 days of sunshine, the dry climate, high altitude, and bracing air, are as beneficial to poultry as they are to people. Colorado feeds—wheat, barley, field peas, and alfalfa are especially valuable for egg production. The field peas of the San Luis Valley produce a specially choice flavor in the meat from poultry.

GRAIN AND GRAIN PRODUCTS.

Wheat	3,750,000	
Corn	2,530,000	
Oats, rye and barley	310,000	
Flour	1,500,000	
Millstuff and corn meal	860,000	$8,950,000
Breakfast foods and food Cereals	1,122,000	
Crackers, wafers, fancy biscuits, etc.	350,000	$1,472,000
Total		$10,422,000

Wheat.—The U. S. Department of Agriculture reports that there were raised in Colorado in 1908 6,153,000 bushels of wheat, and in 1909 9,467,000 bushels. It requires in the state annually for flour, seeding, and ordinary feeding about 5,600,000 bushels. There was therefore a surplus of wheat above home needs, in 1908, of nearly 10 per cent. and in 1909, of 69 per cent.

A large quantity of soft winter wheat was shipped into Colorado in 1909, from Idaho, and adjoining states. The wheat was shipped with milling in transit privileges through Colorado to southern states. It was ground in Colorado and the flour sent south. Considerable hard winter wheat was shipped into Colorado for grinding from Kansas and Nebraska.

Flour.—Colorado bakers do not use flour made from Colorado wheat for bread making. Practically all the bakers' bread in Colorado is made from Kansas hard winter wheat flour. Experts estimate that over one-half the bread eaten in Denver, and four-fifths the bread eaten in Pueblo, is from Kansas hard winter wheat flour.

Most of the families in Pueblo, particularly those connected with the steel works and with the smelters, use Kansas flour. San Luis Valley Millers buy Kansas flour to supply their bakery trade, and Kansas hard wheat flour is shipped to Durango, Telluride, Grand Junction, and other points, to be used by bakeries and hotels.

Flour to the value of about $190,000 was shipped from Minneapolis to Colorado points in 1909. Most of the flour used by Colorado families is made from Colorado soft wheat with a blend of Kansas or Nebraska hard wheat.

While Colorado produces more wheat than is required to make all the flour needed in the states yet flour, costing at wholesale, $1,500,000, was shipped in, most of it from Kansas. Some flour was received from Nebraska, and a little from Missouri and other states.

The reason bakers use Kansas flour is that the hard wheat Kansas

flour absorbs more water than Colorado soft wheat flour. One hundred pounds of Colorado flour will absorb fifty pounds of water; one hundred pounds of Kansas flour will absorb sixty to sixty-two pounds of water, and make good bread, and can be made to absorb seventy pounds of water if the best quality of bread is not wanted. One hundred pounds of Kansas hard wheat flour will make from ten to fifteen more bakers loaves than one hundred pounds of Colorado soft wheat flour. The Kansas flour contains more gluten. Colorado flour made from Durum wheat contains considerably more gluten than Kansas flour, but is not used by bakers, because it makes a dark colored bread.

Colorado soft wheat alone, or with a blend of hard wheat, makes bread of the best quality. In a bread making contest held by the Denver Gas & Electric Company in 1909 with 1200 loaves competing, the first, second and third prizes for the best loaves were won by loaves made from Colorado wheat. Most Colorado families who bake their own bread use flour made from Colorado wheat. Colorado bakers prefer Colorado flour for cakes and pastry, as it is softer and makes pastry more tender and flaky than hard wheat flour.

The flour made from Colorado wheat, and that from the enormous quantity of soft wheat shipped into Colorado from Idaho and adjoining section, and not used in the state, was shipped to Southern states, where it is preferred, because it makes better biscuits and hot bread than hard wheat flour.

The soft wheat shipped into Colorado should have been produced in the state, and it would have required nearly two-thirds as many additional acres to produce it as were seeded to wheat in Colorado.

Some hard winter wheat is grown in Colorado, particularly on the Plains. Millers have been unable to make a flour from it equal to Kansas hard wheat flour. The largest bakers in Colorado find that the most good loaves of bread can be made from hard wheat flour of certain sections of Kansas only and that the hard wheat flour from other parts of Kansas is not satisfactory.

The Kansas localities named by the bakers as producing desirable flour are those that for several years have paid particular attention to selecting seed and maintaining wheat having hard red berries. The sections of Kansas named as producing unsatisfactory flour are those that have allowed considerable of the yellow berry to show in their wheat.

All hard winter wheat raised on the Plains in eastern Colorado examined by the writer has been badly affected with yellow berries. It would seem that it would pay farmers, farmers' organizations and commercial clubs in eastern Colorado to make a united effort to secure pure seed of hard winter wheat entirely free from yellow berries and to grow wheat from which flour can be made equal to the best Kansas flour. It means the securing for the Plains a market that now amounts to $1,500,000 a year and that is constantly increasing.

Corn.—About 3,700 cars of corn, costing approximately $2,530,000, were shipped into Colorado from Kansas and Nebraska in 1909.

Over 350,000 lambs were fattened on this corn. Most of the hogs slaughtered at home and at packing houses in this state were finished on this corn. A large quantity was fed to beef cattle, to dairy cows, and to horses. We found Kansas corn being fed to fattening hogs in La Plata county, 450 miles southwest of Denver.

Much of this feeding of imported corn is done from habit, the farmers who feed it having come from corn belt states. Both barley and field peas produce better pork than corn. Barley is as good a feed for horses and dairy cows, and oats is a better feed. Beef produced at the College showed that the choicest flavored beef can be produced without feeding any corn, and many lamb feeders have shown that good results can be secured in fattening lambs on barley, except just at the finish.

Breakfast Foods and Cereal Products.—Over 1,700 tons of cooked cereals, and over 4,200 tons of uncooked breakfast foods, such as oatmeal and cracked wheat, were shipped into Colorado in 1909. These breakfast foods took out of the state over $460,000. Hominy and Grits to the value of $3,200 were shipped in.

About 760 tons of peanuts were shipped into Colorado, costing $114,000. Peanuts do well on sandy soils on the Plains.

Over 430 tons of macaroni were shipped into the state at a cost of $44,000.

About 1100 tons of starch were shipped into the state, costing about $165,000. We shipped in over 3,000 tons of rice that cost us over $300,000. Rice cannot be raised in Colorado, but it is used largely as a substitute for flour products and potatoes.

Less than one pound of cane sugar for each inhabitant was shipped into the state, showing that the greater part of the supposed cane-sugar used by the Colorado housekeeper must be beet-sugar.

About 145 tons of popcorn were shipped into Colorado from East of the Missouri River at a cost of $7,000.

Crackers, wafers and fancy biscuits were shipped into Colorado that cost $350,000. As our home cracker factories use Colorado products chiefly in manufacturing their goods this sum could be kept in the state by buying Colorado made products.

BROOM CORN

Broom Corn **$96,000**

It requires annually from 500 to 600 tons of broom corn to supply home needs in Colorado, and about an equal amount is shipped into the state, made up into brooms and brushes, and then sent to other states.

In 1909 about 150 tons were grown in Colorado, leaving 450 tons to be shipped in for home consumption, and between 500 and 600 tons shipped in that were sent out later in manufactured goods. A considerable portion of the 450 tons needed for home use was shipped into the state in manufactured goods. About two-thirds of the total amount grown in Colorado in 1909 was produced in Baca county.

Normally good broom corn is worth from $60 to $80 a ton. Some-

times it drops as low as $30 a ton, and at present, owing to a severe shortage throughout the United States, the best grade of broom corn is selling at $275 a ton.

The extreme high price for broom corn is exciting many Colorado farmers, particularly in the dry land sections of Eastern Colorado, and many are planning to raise this crop in 1910 for the first time. Some Colorado farmers who have never raised the crop are planning to raise from 200 to 300 acres each.

Most of these beginners will probably make failures. The growing of a good quality of broom corn is the work of an expert of long experience. The differences between strains of broom corn are as many and as great as between varieties of corn. The successful Colorado grower must start with seed adapted to his locality and seed that will produce a tough quick-growing brush, ripening early, and neither brittle nor coarse. He must prepare his soil and keep it through the season in such condition that a rapid growth is maintained. He must have sufficient teams tools and labor to harvest the crop at just the right time to secure the best quality of brush, and he must have proper sheds and racks for curing the crop. Skill, judgment, and experience are needed at every step.

Most of the broom corn grown in Colorado has been of poor quality, considerable of it almost unsalable in years of good supply. A few experienced Illinois growers who have come to Colorado have produced broom corn of high quality.

Colorado broom corn is generally brittle and rough, and much of that raised under irrigation is coarse. These faults come first from the seed. The cool nights tend to make it brittle. Much of the broom corn raised in the state is damaged by not being harvested at the right stage and by being cured without shelter.

The southeastern part of the state is best adapted to the production of broom corn on account of having warmer nights through the growing season than other sections. It is probable that in this territory a quality of broom corn can be produced that will supply most of the demand of the state, if skilled growers give due attention to every detail in producing the crop and are well supplied with the needed equipment.

It is probable that the warmer sections of the fruit belt in western Colorado are adapted to broom corn.

A good yield is one ton to three acres, on irrigated land, and one ton to four acres on dry land. This gives a good profit in years of exceptionally high prices, a little more than pays expenses in average years, and returns less than cost in years of low prices. Broom corn is a fairly good sod crop. It requires about 4,500 acres annually to supply the demand in Colorado.

HAY.

Hay	$1,450,000

About ten thousand cars of hay were shipped into Colorado in 1909, with an estimated wholesale value of $1,450,000. This hay came

chiefly from Kansas, Nebraska, Oklahoma and Wyoming. Most of it was shipped in to be fed to horses and was hay made from native grasses.

During this same time a large quantity of alfalfa hay was shipped to southern states for feeding work animals—horses, mules, and oxen. Colorado alfalfa hay is in demand in eleven southern States—planters, contractors and other large users of horses, mules, and oxen considering it the best feed for animals doing hard work. Colorado horsemen do not like alfalfa for this purpose.

Colorado men handling large numbers of horses and mules doing heavy work consider that the best hay for work animals is timothy, grown at an altitude of 7,000 to 8,500 feet. The timothy hay grown at these altitudes in Grand, Routt, and Gunnison Counties sells in the wholesale markets of eastern Colorado at from $4.00 to $5.00 a ton more than the hay that is shipped into the state.

Timothy at these high altitudes yields two tons and upwards an acre, and is a profitable crop. Any one of these three Counties has a sufficient area to supply all the hay of this character needed in Colorado markets, but has not the farmers to produce it. Any considerable increase in the quantity of hay produced in these sections will have to be secured from new settlers.

Eleven southern States want Colorado alfalfa to feed to their work animals, and there is a large and continually increasing demand from all the eastern states for Colorado alfalfa hay, and alfalfa meal. Appreciation of alfalfa hay is growing much faster in the United States than is production, and if Colorado had the farmers to grow it, a good demand would be found for many times the quantity of good alfalfa hay than is now being produced in the state.

FIELD SEEDS.

Alfalfa Seed	$150,000
Seed Potatoes	30,000
Timothy Seed	50,000
Sorghum, Kafir, and Milo	6,000
Millet Seed	4,000
Total	$240,000

Alfalfa Seed.—This season, up to February 1st, 1910, 32 cars of alfalfa seed shipped direct from Germany had been sold in Colorado, and importers expect to sell several more cars of this seed before the end of the seeding season. These 32 cars cost, wholesale, $4,300 per car, a total of $137,600.

German alfalfa seed has a very high germination test, but the adaptability of the various German strains of alfalfa to Colorado conditions, and the quality of hay that they produce, have not been determined.

A few years ago Colorado received large shipments of alfalfa seed from Utah, and the alfalfa from Utah seed was found to be particularly adapted to our conditions. Practically no Utah alfalfa seed

is now used in Colorado, for as soon as the trade was established, the Utah shippers began sending seed badly adulterated with sweet clover. Some of the highest priced shipments contained 90% of sweet clover

Some Colorado dealers, after being forced to abandon the Utah seed on account of the sweet clover adulteration, decided to secure seed grown in Arizona; and considerable Arizona alfalfa seed is now on sale in Colorado.

The few tests made of Arizona seed by the Colorado Experiment Station have shown that the plants from it are too delicate for our climate, and begin to rot and die within a year after seeding. Whether this will be true of all alfalfa from Arizona seed we do not know.

Alfalfa seeding in Colorado from seed grown in the western sections of Nebraska and Kansas have shown that seed from these sections is very desirable.

Probably less than half of the alfalfa seed sown annually in Colorado is grown in the state. There is a great opportunity for the development of this industry, as Colorado farmers prefer home grown seed, and if it could be produced there would be great demand for Colorado alfalfa seed in the northern section of the corn belt as well as at home.

Seed Potatoes.—At least 50 cars of seed potatoes are shipped each year into the Greeley district from outside the state, costing wholesale, $20,000. Other parts of Colorado ship in from other states seed potatoes, costing at a low estimate, $10,000, a total of $30,000 per year for seed potatoes shipped into Colorado. Some years nearly twice this amount has been shipped into the Greeley district alone. This seed comes chiefly from Wisconsin, some from Minnesota, and a few cars from Maine.

C. L. Fitch, of the Colorado Experiment Station, has made a careful investigation of the results obtained from this "shipped in" seed. He reports that the average returns in the crop from the seed shipped in is $40 an acre less than that from acclimated seed. The seed shipped into the state is sufficient to plant 4,100 acres, which at $40 an acre, makes a direct loss in the crop each year of at least $164,000. Sometimes double this acreage is planted with seed shipped into Colorado, and the loss is then double the amount given.

On the other hand, for the past two years carefully selected seed potatoes from Greeley sent to the San Luis Valley have produced an average gain in profits of $75 an acre over home grown seed.

About 30,000 acres are planted to potatoes each year in the Greeley district, and the acreage is constantly increasing. If seed could be secured for this district that would give as great an increase in profits an acre as the Greeley seed gives in the San Luis Valley, the additional profits would be enormous.

One of the most promising lines for the potato grower at an altitude of 7,000 feet is the production of seed potatoes grown from seed taken from high yielding hills. When the right seed is developed northern Colorado alone needs 800 cars a year.

Another loss, small to the individual farmer, but large in the aggregate of the state, comes from the common practice of ordering seed potatoes of the new sorts glowingly advertised in eastern seed catalogues. Tests made by the Colorado Experiment Station show that not over one in one hundred of these varieties equals in yield the standard Colorado sorts, and many are worthless.

Timothy Seed.—Most of the large quantity of timothy seed sown in Colorado is shipped into the state. Seedmen state that $50,000 a year is a low estimate of the amount sent out of the state annually for this seed.

Colorado grown seed is heavier and has greater vigor, but Colorado timothy growers perfer to market hay rather than seed. It would seem that there is a good opening for growing timothy seed in Colorado at high altitudes at points too distant from railroads to make the shipping of hay profitable.

Sorghum, Kafir, Milo and Millet.—In a recent examination of sorghum seed from Colorado and from Kansas, Colorado seed averaged in every case heavier per struck bushel than that from Kansas. Colorado grown milo weighed 63 pounds per struck bushel. Colorado farmers should not only supply the demands in the state for these seeds, but should ship large quantities to other states.

FRESH FRUITS, MELONS AND VEGETABLES.

Fruits and Melons not grown in Colorado or shipped in out of season	**$1,237,000**
Fruits that could have been grown in Colorado	367,500
Potatoes and sweet potatoes	184,000
Green Vegetables	195,500
Total	**$1,984,000**

FRUITS AND MELONS NOT GROWN IN COLORADO OR SHIPPED IN OUT OF SEASON.

Oranges	**$360,400**
Bananas	371,000
Lemons	138,000
Strawberries	164,500
Grape Fruit	49,000
Cranberries	42,500
Tomatoes	41,200
Pineapples	35,500
Water Melons	27,900
Figs	7,000
Total	**$1,237,000**

Oranges, bananas, lemons, grape fruit, pine apples and figs cannot be grown in Colorado, but if there were a sufficient quantity of choice, home grown apples and peaches, the quantity of these subtropical fruits used would be greatly reduced, and the money spent for them kept in the state.

Nearly one-third of the strawberries came in out of our season, and were sent from California, Texas, and Arkansas. Two-thirds of the strawberries shipped into the state came from Missouri, and a large part of these should have been produced in Colorado. Some strawberries came from Oregon, and Utah.

The tomatoes came from Florida, Georgia, Texas, Arkansas, essee, and Mexico, and were received before Colorado tomatoes were marketable.

The watermelons came from Florida, Georgia, Texas, Arkansas, and Oklahoma, and were shipped in out of season.

FRUITS THAT SHOULD HAVE BEEN GROWN IN COLORADO.

Grapes	$208,300
Apples	65,500
Cantaloupes	57,200
Pears	33,500
Prunes	8,300
Peaches	5,800
Cherries	1,300
Total	$379,900

One hundred and thirty cars of Concord grapes were shipped into Colorado in 1909, costing, wholesale, $104,850. Half of these grapes came from New York, over one-third from Michigan, and the remainder from Pennsylvania and Iowa.

The writer has purchased New York grown Concord grapes, at Cortez, Colorado. They were shipped from New York to Denver, and re-shipped to Dolores, 510 miles by rail from Denver, having to be transferred at Alamosa to narrow gauge cars. They were carried by freight wagons from Dolores to Cortez, nearly twenty miles. Yet grapes thrive particularly well in the Montezuma Valley, of which Cortez is the center, and the few vineyards there yield $500 and upwards an acre a year.

California grapes to the value of $91,000, and Imported grapes to the value of $12,450 were shipped into Colorado in 1909. Professor O. B. Whipple, formerly Field Horticulturist for the Colorado Experiment Station, states, in Bulletin No. 141, that California varieties of grapes grow in the fruit section of Colorado will, when mature, give an average annual return of $525 per acre, and Concord grapes an average annual return of over $600 an acre. One of the most successful apple growers in Canon City stated to the writer that grapes planted between rows of bearing apple trees have given him, for twenty years, an average annual return per acre of $100.

The fruit sections of western Colorado are well adapted to grape growing, and it is an industry that offers quick returns. If there were a sufficient number of men to grow them, Colorado could not only fully supply the home market, but the demand in all the other mountain states.

Apples.—About three-fourths of the apples shipped into Colorado in 1909 came from California. They were inferior in flavor, size, and coloring to Colorado apples. Other shipments were made from Oregon, Utah, Montana, and Kansas.

In a trip made by the writer in November and December, 1909, covering the dry land sections of eastern Colorado, it was found that the towns in these sections along the lines of the Burlington, Union Pacific, Rock Island and Missouri Pacific railroads were supplied almost entirely with California apples. The fruit growers of the eastern Slope and of the Arkansas Valley should organize and secure this trade. It is a market that can be greatly increased.

Potatoes and Sweet Potatoes.—Potatoes for the table use to the value of $116,000, and sweet potatoes to the value of $68,000, were shipped into Colorado in 1909.

About half of the potatoes came from Texas, the others from California, Utah, Idaho, Arkansas, and Kansas. Most of the potatoes came in before Colorado potatoes were ready for the market. In February, 1910, a car of new potatoes was received in Denver from Cuba.

Over half the sweet potatoes came from Kansas, one-third from Virginia, and the others from California and New Jersey. From limited trials, it seems probable that the sandy soils in the Arkansas Valley are well adapted to growing sweet potatoes, and that this section should furnish all the sweet potatoes needed in the state, and in other mountain sections.

Green Vegetables.—Cauliflower, cabbage, celery, and onions were shipped into Colorado from California, celery from Florida, cabbage from Tennessee and cabbage and onions from Texas. The growers of these products in Colorado need to pay more attention to the early crops, and to methods of storage that will lengthen the period of home grown supplies.

CANNED GOODS.

California Fruit	$500,000
Corn	310,000
Tomatoes	300,000
Peas	80,000
Beans, Succotash, Sweet Potatoes, Beets, Asparagus and other vegetables and eastern Berries and Fruits	100,000
Grape Juice	35,000
Cider	20,000
Total	$1,345,000

This estimate is conservative. Some of the largest jobbers in the State consider that the actual total is nearly $2,000,000. The most careful estimates place the value of canned goods put up in Colorado, in 1909, at $500,000. The business in the state is increasing every year.

Fruit.—Most of the canned fruit sold in Colorado comes from California, some of it from states east. There is a great opportunity for the fruit growers of western Colorado not only to supply the demand for canned fruit in Colorado, but the demand for the best quality in many other states.

Colorado canned fruit, when properly prepared, is as much superior in flavor to canned fruit from other sections as Colorado fresh apples and peaches surpass those from other states. Only a small proportion of the fruit trees in the fruit sections of Colorado have reached the age of bearing, and in a few years the fruit output of the State will be increased many fold.

As fruit production increases, the canning industry can be gradually established, and the knowledge and skill acquired to produce a canned product uniform and equal in quality to that of our fresh fruits.

Corn.—The best grade of canned sweet corn comes from Maine. The bulk of this product shipped into Colorado comes from Iowa, Missouri and other states in the corn belt.

A few thousand cans were put up at Fort Lupton, Colorado, in 1909. In most of the tillable sections of Colorado the nights in summer are too cool for the best growth of sweet corn. The Arkansas Valley and the warmer sections of the Western Slope have conditions well adapted to the growing of sweet corn for canning, except the damage from boll worms in the ear. In some seasons the worm damages almost every ear, and in other seasons the damage is very slight, but the uncertainty prevents the growth of the sweet corn industry.

Tomatoes.—Experts estimate that 7,200,000 cans of tomatoes were eaten in Colorado in 1909, one-half of which were shipped into the State. Most of the tomatoes shipped into the State came from the corn belt, though large shipments were made from California, and from as far east as New York.

Fifty thousand cases of tomatoes were shipped into Colorado from Utah. These tomatoes were grown under conditions almost identical with those found in the fruit sections of western Colorado.

Tomatoes do well in several sections of Northeastern Colorado and the soil and climate of a large proportion of the Arkansas Valley and of the Western Slope fruit sections are suitable for growing large yields of tomatoes of good quality.

The industry should grow until most of the canned tomatoes used in the State are a home product, and the quality that can be produced in Colorado will find a good market in many other states.

The objection made by retail grocers and by consumers to tomatoes canned in Colorado is that they are not uniform in quality. Several cases may be as uniform in character and of as good quality as the best or the most expensive brands of eastern canned tomatoes, while in the same shipment, from the same factory, will be other cases that contain cans whose contents are watery, often to a serious

degree. California canned tomatoes often have the same fault.

Some expert handlers of canned tomatoes believe that this condition is largely caused by over irrigation and that it is made worse by the use of seeds from strains that do not produce firm fleshed tomatoes, by too little cultivation and by a too high temperature in canning.

The best canned Colorado tomatoes are equal to the best produced in any other part of the United States, and the industry needs the intelligent co-operation of the seedsmen, growers and canners to produce a uniform quality of high grade.

Peas.—The peas canned in Colorado by Empson are equal in every respect to the best grades of canned peas produced anywhere else in the world, and if a sufficient supply was produced, they could be sold anywhere on the globe where canned peas are wanted. They are the only canned peas produced in the United States equal to the French peas.

About 90% of the canned peas used in Colorado are from the Empson factories, and most of the peas that are shipped into the state are brought here because jobbers want their own names on the cans and the Empson factories refuse to do this.

Beans, Succotash, Sweet Potatoes, Beets, Asparagus, and Other Vegetables.—These can profitably be canned in Colorado in quantity and of the quality required to supply all the demands of the state.

Canned Goods.—This industry can be developed until a sufficient quantity is produced not only to supply the demands of Colorado, but a much larger market in other states. Before this can be effected a uniform, choice quality must be produced season after season.

The Empson canned peas produced in Colorado are not surpassed by those produced in any other part of the world. Mr. Empson determined the most suitable varieties the best strains of these varieties, and the methods and locations for producing and maintaining seed that will secure high quality in the crop. He ascertained the character of soil that will produce the choicest flavored peas, and he allows peas to be grown on that kind of soil only. The methods of planting, cultivation, irrigation and canning that produce the choicest quality of peas were all discovered and then adopted.

It will require similar methods to give Colorado canned fruits, berries, tomatoes and vegetables the same standing through the United States that is now held by Colorado fresh fruits and potatoes. Many towns in Colorado are planning to establish canning factories. Such factories will be profitable only when methods like those of Mr. Empson are adopted.

DRIED FRUITS.

Dried Fruits **$500,000**

A large proportion of the dried fruits shipped into Colorado come from the Pacific Coast.

The dried fruit industry has been started in a small way on the Western Slope in Colorado. Apples, peaches and prunes make up the bulk of the product.

Jobbers and grocers complain that Colorado dried fruits fail to be uniform in quality, and state that the production of dried fruit will have to go through the same stages of development through which the production of fresh fruits and potatoes has passed before Colorado dried fruits will have a high standard in the markets of the United States.

PICKLES, CATSUP AND CANNED BEANS.

Pickles (Colorado Sorts)	$50,000
Catsup	50,000
Pork and Beans	75,000
Total	$125,000

Pickles.—The pickle industry is comparatively new in Colorado, and is annually increasing. The pickles put up by those of our manufacturers who are skillful and have had experience are fully equal in every respect to pickles shipped in from other states. Growing material for pickles gives good profits to the farmers who understand the business and the industry is likely to have a continual steady growth.

Catsup.—Some Colorado catsup is equal to the best eastern brands and some is of poor quality. Consumers do not feel certain of the quality and many prefer to buy eastern brands that are good and always uniform. Greater care on the part of all Colorado makers of catsup could overcome this difficulty.

Pork and Beans.—The large demand for eastern brands of pork and beans seems to have been created largely by the expensive advertising given these brands in magazines and ladies' journals.

WHAT THIS INQUIRY SHOULD SHOW COLORADO PEOPLE.

This investigation shows that over *Thirty-one Million Dollars* were sent out of Colorado in 1909 to buy agricultural products that should have been produced in the State. This heavy drain on the State is annually increasing.

The entire output from the metal mines of Colorado, for 1909, as reported by the State Commissioner of Mines, Mr. T. J. Dalzell, to be $33,211,527, as follows:

Gold	$21,946,684
Silver	4,587,643
Lead	2,765,512
Copper	1,220,642
Zinc	2,295,046
Tungsten	396,000
Total	$33,211,527

The gross returns from our metal mines was but little more than sufficient to pay for the agricultural products shipped into this State. The gross product of our silver mines was not quite sufficient to pay for the dairy products shipped into the State. The gross returns from silver, lead and copper were slightly more than enough to pay for the meat and meat products shipped into Colorado. All the zinc mined would a little more than pay our bill for eggs shipped in.

Nearly every agricultural product shipped into Colorado could have been more easily produced in the State, at a greater profit, and under conditions more enjoyable for the producer than in the sections where it originated.

The following figures from the United States Department of Agriculture show the average yearly yields per acre for the past ten years, and indicate the larger yields in Colorado:

	WHEAT Bu.	OATS Bu.	BARLEY Bu.	POTATOES Bu.	HAY Tons
Colorado	24.5	34.2	33	122	2.31
Indiana	.....	29.1	25.6	77	1.36
Illinois	.....	31.3	28	85	1.33
Iowa	13.8	30.1	26	83	1.52
Kansas	11.6	24.4	19.7	77	1.42
Nebraska	12.6	26.9	24.4	84	1.57
Wisconsin	15.7	33.4	28.8	92	1.56
Minnesota	12.7	31.6	25.8	86	1.66

Although Colorado produces high yields of grain, yet ten million dollars were sent out of the State in 1909 for grain and grain products. The conditions of climate are ideal for growing beef animals, and the feeds produce beef of a choice flavor, yet one million eight hundred thousand dollars were sent out of the State for fat cattle, beef and veal. Pork can be produced at less cost and of better quality than it is being produced in the corn belt. We sent out in 1909 over four million dollars for hogs, pork and pork products. Both climate and feeds are adapted to the economical production of dairy products, still we sent out nearly five million dollars for these products, alone. Four million dollars were sent out for eggs and poultry, while our few expert producers of these products were making nearly double as much, per hen, as was being made in the States from which we made these purchases.

Why, then, with such favorable conditions, did we send out thirty-one million dollars for agricultural products that could have been more profitably produced in the State? Because there was not a sufficient number of farmers in the State. Almost every farmer in Colorado is undertaking more than he can accomplish well, and it will be impossible to increase the present agricultural output of the State to any considerable extent, unless we secure more farmers.

With many products shipped into Colorado, the consumption ould be larger could home products be secured. When people are bliged to use cold storage eggs, the consumption drops to a frac-on of that when fresh layed eggs are available. More meat, more utter, more cream and milk, and more fruit and vegetables are ten when strictly fresh, home produced products can be secured.

We need 30,000 more farmers this year in order to produce the gricultural products that will be consumed in the State. We need en who are skillful in the management of beef and dairy cattle, gs and poultry; grain, fruit and vegetable growers, and men who n produce choice raw material for canning and pickle factories.

The potatoes and fresh fruits grown in Colorado have a Nation-reputation for choice quality and there is every reason to believe at if a surplus above home needs were produced, a large mand could be created in other States for Colorado meats, dairy oducts, poultry and eggs, seeds, canned goods, and dried fruits. will require thousands of farmers to produce a sufficient surplus these products to secure a large outside market.

SECURING ESTIMATES.

The figures given in this bulletin are estimates only. They are sed on the most accurate data that could be secured and are con-rvative estimates, considered in many cases by the largest handlers the products to be low.

The writer has had charge for over three years of the Farmers' stitute Work of the Agricultural College and during that time has aveled over 60,000 miles in Colorado. During the three years he d his associates from the college in Institute Work, 35 in num-r, have been collecting data in regard to the agricultural products iginating in the State and those shipped in. The data so obtained ve been used as the basis for these estimates.

In addition to the above information the railroads furnished us ith a statement of the exact number of tons of each agricultural oduct from the Missouri River, Eastern and Texas points that ere shipped in 1908, and in the first four months of 1909, into, but t through, Colorado, to Denver, Colorado Springs, Pueblo, Trini-d and other points by way of the Santa Fe, Burlington, Rock Is-nd, Missouri Pacific, Union Pacific, Rio Grande and Colorado & outhern Railroads. These figures were used as the basis for esti-ates where accurate statements for 1909 could not be secured.

The Rock Island and the Denver & Rio Grande furnished state-ents of the exact tonnage of all agricultural products brought by these railroads in 1909.

The Burlington and Union Pacific Railroads furnished us the nnage of grain and grain products brought by them into Colorado 1909, and the Union Pacific gave us a statement of the tonnage of y brought into the State by that railroad in 1909. The Santa Fe ailroad furnished us a statement of the tons of grain and grain oducts brought into Colorado in 1909 by that road.

The Denver Union Stock Yards furnished a statement of the number and value and origin of all fat animals shipped into Colorado in 1909.

The quantity of meat and meat products shipped into Colorado in 1909 was secured from the railroads and the values were furnished by the experts from the Colorado Packing Company.

The estimates on the value of butter and cheese was made after securing figures from all the large handlers of these products.

The estimates on eggs were made from the combined estimates of eight of the largest handlers of these products in the State, together with information obtained during the past year by Professor Vaplon, the Poultryman of the Agricultural College, and myself in most of the towns in Colorado. The estimate on poultry was obtained in the same way, and in addition, information was obtained in regard to the amount being sent out of Colorado through the banks for poultry.

The estimate on condensed milk was secured from the Condensed Milk Factory at Fort Lupton, and from the jobbers of this product at Denver, Colorado Springs and Pueblo.

The estimate on Malted Milk was secured from wholesale and retail druggists.

The information in regard to grain and grain products was obtained from railroad records, from millers, from wholesale dealers in flour and feed and from bakeries.

Seedsmen in Denver and Pueblo and records from railroads furnish the information in regard to seeds.

Data in regard to fresh and dried fruits and vegetables were secured from jobbers and brokers and the records of the railroads. Mr. Geo. Knifton, Denver, was particularly helpful in securing this information. The estimates on canned goods, pickles and condiments are based on information furnished by the largest jobbers in these products in the State, and by canning and pickle factories.

The estimates on hay were based on records of shipments furnished by the railroads and information given by large handlers of this product. The information in regard to broom corn was secured from the chief handlers of this product in Denver and Peublo.

We shall be very glad to receive corrections and additions to these estimates from any reliable source.

Bulletin 154 April, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

ALFALFA STUDIES

THIRD PROGRESS REPORT

BY

P. K. BLINN

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The Agricultural Experiment Station

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REPORT OF ALFALFA INVESTIGATIONS.

By PHILO K. BLINN.

The attempt to improve the hay and seed yielding traits of lfalfa, by systematic seed selection, has had decidedly encouraging esults; although it may yet require several years of close observaion to fully determine the best types for hay and seed production.

The conclusions from some of the observations, have been ather doubtful, and there are reasons for discounting the value of ome of the contrasts that have appeared; for instance, the selecions, for ideal leaf, and stem qualities, made the first season, durng the seedling growth of the plants in the nursery, have since roven of little value, as there was a decided change in the type of oliage, when the plants took on a more rapid and succulent growth: he same result would follow, as the effect of environment, rather han heredity, for any trait that might appear; hence, the problem s to select plants that have an inherent power for the reproduction f desirable qualities; but, with nearly a hundred strains to consider, nd at least a score of points of variation appearing in endless comination, this has not been an easy undertaking.

Several of the varieties tested, show contrasts of decidedly ratical value, such as, *hardiness, habits of stooling, qualities of esistence, to drouth, frost* and *fungus diseases, leafy hay qualities* nd *prolific seed yields.* These valuable traits are not found in any ne variety, and it is difficult to say which strains, have the points f greatest utility; it is certainly obvious, that marked improvement ver most of the ordinary types, of alfalfa is possible, if only seed f some of the strains tested, could be procured, which however, is ifficult, as different lots of seed supposed to be the same, often rove entirely different.

It is impossible to identify the seed origin of a field of alfalfa, nd it is equally difficult, to make varietal distinction, in the points hat are casually observed; for with few exceptions, the same colred flowers, the same shaped leaves, and the same general type of lants, may be found in nearly all varieties, and there is often greater range of variation in the individual plants of a single train, than in the contrast of so called varieties.

It is difficult to judge the merits of alfalfa, growing under ifferent conditions of soil, and cultural care; but, in a *comparative est under uniform conditions,* the *contrasts* are *clearly shown,* also n *nearly all varieties* it is *easy* to *recognize* the *superior qualities of ome of the individual plants;* which suggests the SINGLE PLANT as he UNIT *for seed selection.*

The results of our nursery work with *individual plant selecions* have revealed the facts, that in plants, showing desirable ualities, *some* will reproduce the traits, quite *uniformly true,* while

others, will breed *irregularly* the *qualities,* that were *apparently the same;* hence, *heredity* in alfalfa plants *can not be determined, by a cursory view,* but more by the comparison of their *performance records.*

The plan is now, to make individual selections of seed from the *most highly efficient plants,* revealing desirable traits, where ever found, in any of the varieties, and then submit them to a fair comparative test for their reproducing tendency, thus, affording an opportunity to intelligently select and increase seed of alfalfa, with known uniformity, of qualities, for testing in different sections of the state. Some of the principal qualities, that have engaged the attention in this investigation are—*Hardiness,* there are few fields of alfalfa that have not suffered from the lack of this trait, plants dying out, either form frost, drouth, soil conditions, or plant diseases. The superiority in this respect, of the Turkestan and more hardy kinds, over the Arabian, or southern variety is very marked indeed.

PLATE I. CONTRAST OF HARDINESS BETWEEN SOUND TURKESTAN AND UNSOUND ARABIAN PLANTS

The contrast between two, two year old plants, from the nursery, can readily be seen, one perfectly sound, the other with the crown nearly all rotted off, and each having grown under the same conditions, and also representing fairly the condition of the plants, in the plats from which they were taken; showing a lack

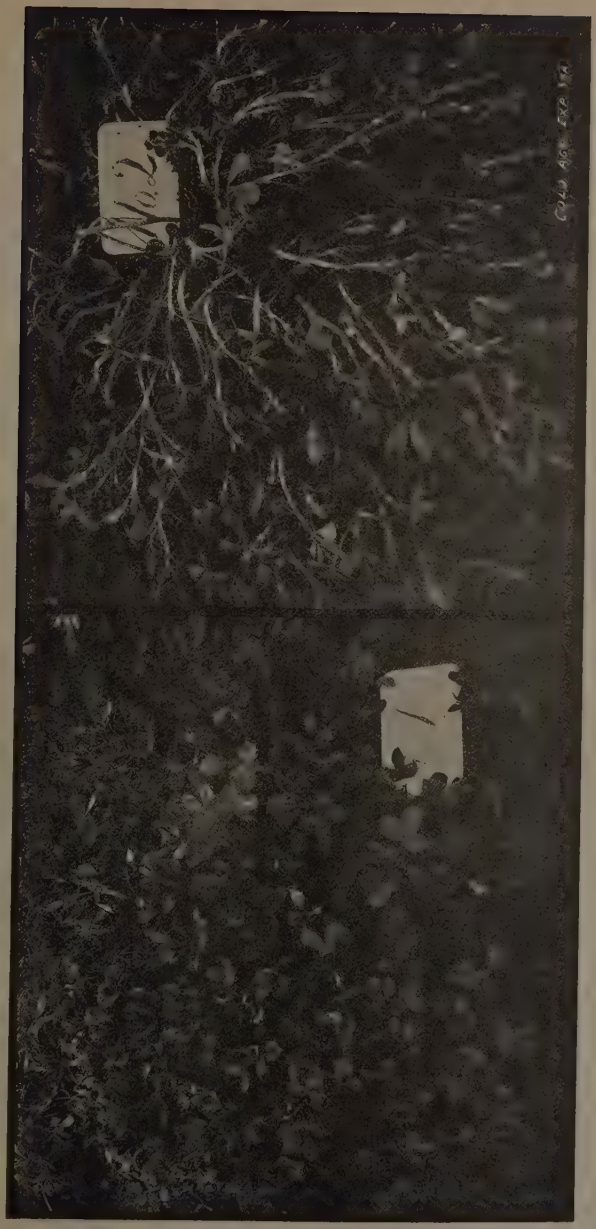

PLATE II. Two Adjacent Turkestan Plants, May 3, 1909, Two Days After Freeze of 18°
No. 1. Dark green foliage pratically uninjured.
No. 2. Light green foliage; leaves and stems entirely frozen back. Both U. S. P. I. No. 18,425

of vitality. Another contrast along the same line, was in regard to the *frost resistance* of the *green growing plants;* on April 26, 1908, the weather dropped to 22 degrees of temperature.

The alfalfa in the nursery plats, a foot in height, was frozen stiff, but when the sun thawed them out, some plants were exceptionally free from injury; *the light colored foliage,* seemingly to have suffered most.

The past season, the temperature dropped to 18 degrees, on the last of April, and the alfalfa was again severely frozen back, and with the same results, of a contrast in resistence, but not uniformly in the same plants as the year before, but the *dark green colored plants*, were the most frost resistant. As a variety, the Turkestan plats, were the least injured; two plants from a plat of Turkestan

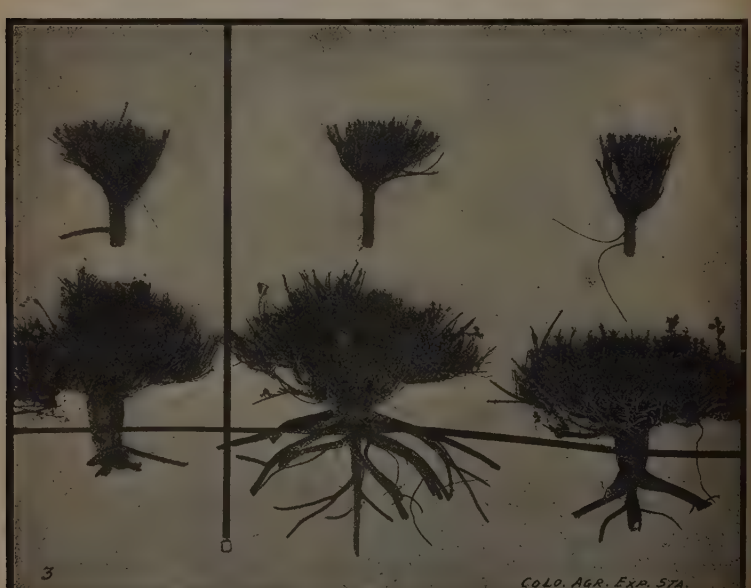

PLATE III. CONTRAST OF STOOLING HABITS

alfalfa, U. S. P. I. No. 18,425, show marked contrast in this trait.

Several plants showing frost resistance have produced seed, which has been secured for future testing for this feature.

One of the most valuable qualities in the alfalfa plant, is its *habit of stooling,* and its power to push out growth for three to four crops of hay a year, almost indefinitely; the nursery plats having been thinned to single plants twenty inches apart each way, gave

an excellent chance to observe the stooling habits of the different varieties; here again the Turkestan plats were exceptionally good, better than any other; and in some plants there is a *tendency* to *root down, from* the *crown branches,* which would be a very desirable trait, to thicken a poor stand, or to maintain a stand of alfalfa on poor soil condition, if it could be better developed.

A contrast in stooling habits is shown in Plate No. III, the larger being from the Turkestan plats, compared to common alfalfa, with main roots over an inch in diameter. In each case, the plants are three years old.

The tendency to start growth early in the spring, is a variation that is characteristic of the Turkestan alfalfa, and some others; as early as March 17, in 1908, these strains were showing green shoots three to five inches high, above the ground, while under the same conditions, the native and some other strains, remained dormant full three weeks later. It has now been observed, that a corresponding check in the growth of these very early varieties, takes place late in the fall, and it is doubtful if this variation is of any value, for the crops in the spring, are so often set back, or cut short, by the late spring freezes.

Our observations, and the reports from several other sources, have been to the effect, that horses will prefer the Turkestan alfalfa in a pasture, over the ordinary kinds. This fact seems to be well established, but a comparison of the different varieties, has not been made, nor has the reason for this preference been demonstrated, but it is doubtless due to a better flavor that the horse appreciates.

The contrasts in disease resistant tendencies, in alfalfa are sometimes very marked, but the plats that have been most affected by a disease one season, have not always been the same ones the next; so there seems to be a little question, as to the reliability of these observations. As in the case, of frost resistance, it is the dark green colored leaves that seem to be the least affected by the mildew or "leaf-spot."

The presence of leaf fungus affects seriously the leafiness of hay, and the search for plants that were the least affected, have been carefully sought in our seed selections.

The richest part of alfalfa hay is in the leaves and small stems, hence, a dense foliage, giving *a high per cent* of *"leaf-to-stem" quality* should be a dominant point in the selection for hay type; and selections for this point have been carefully made.

Plate No. IV, shows the contrast in the uniform production of leafy traits, in two rows, sown last May with the seed of apparently equally good selections, for this trait.

All the desirable points previously mentioned, have not been found associated with the most ideal types for hay, but a wider selection may secure the desired end.

The selections for *seed yielding traits*, have been very positive in their results, and the contrast in the production of seed in the different varieties, have been the most marked of all. Most of the Turkestan plats producing practically no seed, while others among the sixty-four plats in the nursery, have produced the phenomenal

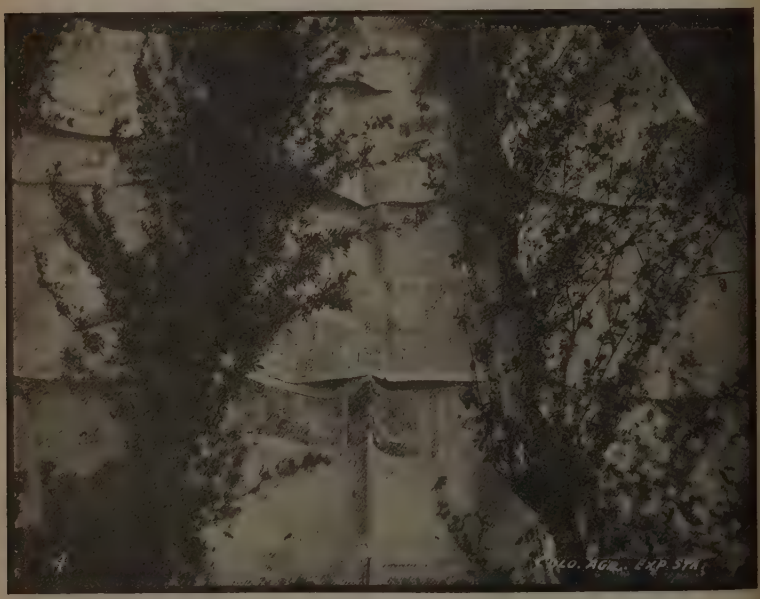

PLATE IV. CONTRAST IN LEAFINESS

yield, of two and one half pounds of clean seed, from a square rod, with less than one hundred plants.

The varieties that have been the heaviest seed yielding ones, one year, have also, been the best the following season; single plants have produced two ounces of clean seed, and the plats sown with the seed of these selections, have in turn been heavy seed producers; so that this trait is to some extent an inherent quality. We have made over a hundred selections of individual plants showing desirable qualities, and Plate No. V, shows the comparison in seed yield of a few of the average plants.

While the seed yielding tendency, may be greatly affected by the hereditary traits, it is doubtless more generally influenced by

the *climatic* and *cultural conditions.* All the observations on this point seem to indicate the fact, that outside of insect injuries, the *proper supply* of *moisture,* is the greatest factor in determining the seed yield of alfalfa. The heaviest yield of seed is produced, when the plants make a relatively *slow dwarfed growth.*

Under irrigation, the usual system of flooding supplies too much water, and the alfalfa grows too rank for a seed yield; on the other hand, without irrigation, the seed fails so often, to fill, on account of the lack of water. But where the roots can penetrate to *just* the *proper condition* of *moisture,* or when irrigation is applied, at just the right time and amount, the happy medium is reached, and a good yield of seed is realized.

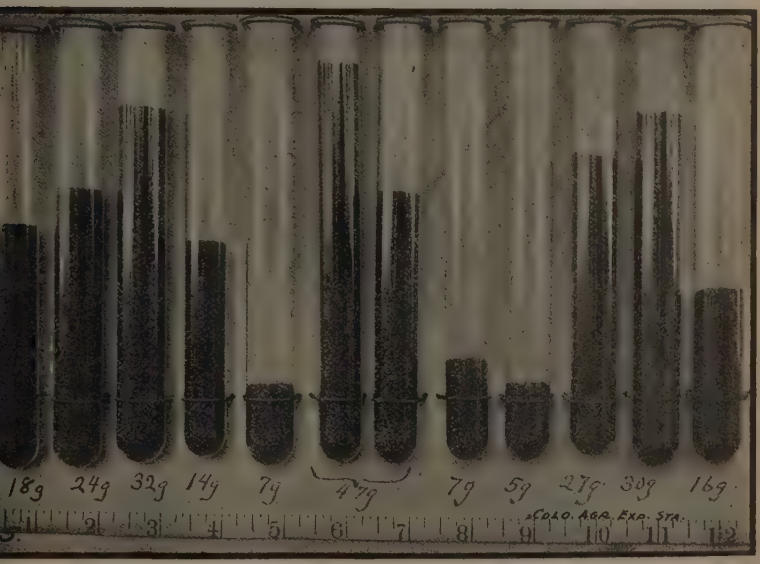

PLATE V. CONTRASTS IN SEED YIELD OF INDIVIDUAL PLANTS

Samples taken at random. Beginning at left, No. 1, Argentine; No. 2, Arizona; No. 3, dry land, Nebraska; No. 4, from Rocky Ford; No. 5, Turkestan; No. 6 and 7, U. S.; No. 8, U. S., No. 17,698, northern Montana, evidently Turkestan, 7 grams; No. 9, dry land, Nebraska; No. 10, Highmore, S. D.; No. 11, Argentine; No. 12, Argentine.

The only practical method to regulate moisture, or to control irrigation for alfalfa seed culture, is to sow the seed *in rows with space,* to permit intertillage to conserve the moisture from rains or winter irrigations, and to enable the rows being "logged" out with clear cut furrows, in about every other row; so that the lightest

possible irrigation may be applied quickly and evenly at the proper time, as the needs of the crop may demand.

A *thin stand* of *plants* on the ground, seems also necessary to produce good results in seed yield. The stems growing more stocky, and the plants standing some little space apart, the branches will entwine each other, so as to *brace,* and *prevent lodging from wind* or *heavy storms,* which is disastrous to an alfalfa seed crop.

PLATE VI. A FIVE ACRE FIELD OF ALFALFA IN ROWS TO TEST SEED PRODUCTION

The smooth furrows will also serve to provide good drainage from excessive rains.

This system has been followed in the nursery plat work, and it has been successful apparently. The plan has been reported a success in other states, and it seems practical, to be applied on a large scale for growing seed commercially.

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THE FIXATION OF NITROGEN

IN SOME COLORADO SOILS

BY

WM. P. HEADDEN

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THE FIXATION OF NITROGEN IN SOME COLORADO SOILS.

By WM. P. HEADDEN.

It has often been claimed that "black alkali" exists in Colorado. This idea has arisen because of the existence of certain black or brown spots which are met with in some localities. The color of these spots is not due, as has been supposed, to the presence of sodic carbonate, to which the name of black alkali has been applied, but to other causes. This salt, sodic carbonate, constitutes a very small percentage of our alkalis and occurs in but one section in such quantities as to be injurious to vegetation. There are several independent occurrences of this salt in the section alluded to, but they are close together and are within an area of a few hundred acres. This occurrence has nothing in common with that of our alkalis, it is not disseminated through the soil but constitutes lakes of sodic carbonate, small ones, it is true, but real lakes having apparently no connection whatever with the surrounding country. The source of this sodic carbonate is without doubt certain underground waters and has no direct relation to the formation of carbonates in semiarid countries. The soils of Colorado do not contain any deleterious quantities of this salt and the so called alkalis seldom contain any large percentage of it. The composition of Colorado alkalis has been a subject of investigation practically all of the time for the past fourteen years or more and it is pretty well established that there is but one type of alkalis in the State and that this is the white alkali, namely, a mixture of sulfates with some chlorids and carbonates, the latter ranging from nothing to 10 or 11 per cent. We have some variations based on the respective bases which may be predominant. The term alkali is used to designate any and all efflorescent salts which form white coatings on the soil or the grass, sticks, etc., which happen to be present and protrude from the surface. The popular term does not take cognizance of the chemical distinction made between alkalis and alkaline earths and the term is here used in its popular and readily understood sense. In some places, due to easily recognized conditions, we have almost pure calcic sulfate, in others, sodic sulfate, and in one rather large section magnesic sulfate is very abundant. We have no type in which either sodic chlorid or sodic carbonate can be said to be really abundant. We have examined some soils with the express purpose of trying to find out whether it would be reasonable and right to attribute their unproductiveness to the presence of salt, sodic chlorid, but no justification for such a conclusion has been found except possibly in two cases. The soil samples chosen were such as were believed to possibly owe their unproductiveness to this cause.

The areas involved varied greatly in size, some of them were very small. This was the case with both of the samples which might be considered as containing salt enough to be detrimental. The data at my command indicates that about 1.5 per cent of the soil is the superior limit which most plants can endure, though 1.8 per cent is given for some. The highest percentage for water soluble chlorin obtained from any soil is 1.025; the highest percentage of total chlorin is 1.887 per cent. As the highest percentages of chlorin are scarcely above the maximum of tolerance for some plants and these have been obtained from two small spots only, the question of chlorin may be neglected in considering the bigger features of the subject even if applicable to these isolated examples.

It is a fact recognized only by a few persons so far that we have in Colorado some very serious problems. On some of our soils the agricultural results, even under the best of practice, present surprises and disappointments. A well trained and experienced agriculturalist made the remark very recently that the results from an agricultural standpoint grew worse instead of better as the practice of the people approached more nearly to those standards which have been and are recognized as the best. This is no exaggeration but represents a real difficulty. Melon growers have noticed for several years that their old grounds have not been producing the same good grade of melons that they produced in former years. In some sections the quality of the sugar beets has shown a falling off. These are general effects the causes of which may or may not be difficult to trace out. It is in specific cases of injury, in exaggerated cases of the operation of such causes that we may best succeed in tracing them and such is the case in this matter. The diffused action over square miles is not intense enough to make definite recognition or a reasonable interpretation of the facts possible. It is only by the aid of extreme cases that we acquire the data whereby to interpret the ordinary manifestation of the cause. In looking over a field in a high state of cultivation, especially a few days after irrigation, the appearance of broad brownish lines just at the outer edge of the irrigation furrows is not a striking feature and usually would be interpreted that the land had been heavily fertilized, or was rich in humus matter, but under no consideration that it might be indicative of danger. My attention was directed to a melon patch last season, 1909, which was sick, this is the term used. There was no rust, no insects, nothing visible to indicate disease. The melon plants were, however, puny and unthrifty. The soil was in fine condition and had been cultivated for several years and fertilized. A melon patch on adjoining land which had been in alfalfa was healthy and vigorous. These plots were separated by the usual wire fence; the soil was the same; the water

used for irrigation the same; the cultivation in both cases was excellent; the men were not new hands at growing melons, the only difference was that the one patch was on a piece of recently broken alfalfa ground and the other on ground that had been cropped for several years. There were no features of either soil which would suggest to anyone not conversant with certain facts, that there was any difference in these fields suggestive of any explanation for the difference in the growth of the plants. It was only after having these certain facts forced on my attention for years that they really became suggestive to me.

The brown lines along the edge of the irrigation furrow might mean heavy fertilization with barnyard manure; it might be due to other perfectly harmless if not beneficient causes, but in these cases they are probably significant of the causes producing the difference in the growth of these young plants. We do not hope in the present bulletin to succeed in tracing out general relations, this is a work for the future concerning which we only promise that it will be prosecuted diligently, with the care and conservatism that its importance demands. It is proper that we should meet the questions presenting themselves in our agricultural practices with only one view, to find out the facts as they obtain at the time without predicting results; though they seem to be already certain and only lack verification. For these reasons no attempt or but little attempt, will be made to more than set forth some facts which have been established, reserving much detail work and the extension of this work in bacteriological lines for the future. Work of this kind is already in progress and some results have been attained, but the work is not ready for publication.

No one can foresee what the problem of the fixation of an excessive amount of nitrogen in our soils may develop into, whether it means the introduction of a new practice or a serious difficulty which we may not be able to control. It may for a while present difficulties because we know but little about such a thing. But if it should prove to be a permanent condition in our soils I am certain that we shall be able to find some remedy perhaps not immediately, but quickly.

Fortunately the trouble expressed itself locally with great violence during May and June of 1909. By fortunately it is not meant that it was a good thing that certain persons suffered loss but simply that the loss was so severe that the people of whole neighborhoods have seen with their own eyes, that something is very seriously wrong, for the sudden death of a large portion of an orchard is convincing proof of this. At this time the foliage of many trees, apple trees mostly, showed a burning, beginning at the apices of the leaves, extending rapidly along the margins until the

whole leaf had turned brown and was of course killed. Many trees died from this cause. Plate I shows leaves with burned edges. This trouble was not confined to any one section but was common to several sections of the state. While it, in all probability, depends upon soil conditions, these conditions are met with in so many places that it is necessary to consider the condition rather than the soil itself. It sometimes occurred in light and sandy loams and sometimes in clayey soils. It is sometimes in comparatively low lying lands, again in the lower lying portions of higher lands and again on hillsides. The road side, a ditch bank, and the cultivated fields represent the range of places in which this thing may reveal itself. There is one thing common in all of its occurrences, namely, a brown color in the surface soil. This color is less marked in the sandy soils than in the so-called adobe soils. Perhaps this is due to the presence of deliquescent salts on the surface of the adobe soils, or more probably to the color of azotobacter films.

The preceding gives in a very general way the big features of the question forming the basis of this bulletin. We have certain soils, quite generally distributed throughout the principal sections of the state, which develop what is popularly known as "black alkali" but the popular judgment in regard to the cause of the dark color is wholly wrong because they have adopted the term from California, where it has a fixed and definite meaning, which is not applicable to our case. While it is not advisable to do so we may occasionally use the term because these dark spots are designated by the people as "black alkali." Nitre spots will, however, be used as the equivalent of the popular term "black alkali." We have so far as is now known, no land, unless it is some near a peat bed, to which the term "black alkali" properly applies.

Reports of black spots on which "nothing will grow" have been received at this department quite frequently during the past four years, and occasionally prior to that time. While at work in the San Luis Valley several years ago, my attention was called to what was supposed to be indications of petroleum. We drove through a small section of the country and observed quite a number of round, black spots absolutely devoid of vegetation, the surface was glistening and appeared as though wet. It was frequently the case that these bare areas were occupied by an ant hill but a great many of them were not. I mention this because I thought at first that the ants might have something to do with the color and appearance of these spots, but there were too many spots without ant hills in order that this should hold true.

Samples from the surface of these spots proved to yield 13.4 per cent of their air dried weight to water, and on evaporation this soluble portion proved to be so deliquescent that it could not be

evaporated to dryness at 100° C. and was finally dried at 160° C. at which temperature it smelled faintly acid. Incipient decomposition had taken place. This analysis, as all of those given in this bulletin, presented some difficulties, which every chemist will recognize and for this reason moisture, organic matter, etc., have simply been given as loss.

ANALYSIS I.

WATER SOLUBLE PORTION OF SOIL FROM BLACK SPOTS.
Laboratory No. 584.

	Per Cent.
Calcic Sulfate	46.883
Sodic Chlorid	10.032
Calcic Nitrate	12.072
Magnesic Nitrate	17.878
Sodic Nitrate	6.033
Potassic Nitrate	5.871
Silicic Acid	0.365
Loss (water, organic matter, etc.)	0.861
	100.000

The sum of the nitrates is 41.859 or 5.628 per cent of the surface soil.

This analysis represents a spot possibly 12 feet in diameter and almost circular. This is, taken alone, no large area but there were a number of these spots all entirely devoid of vegetation, most of them black and glistening. There were others occurring under different conditions, namely, as round or elliptical, somewhat elevated spots and these, too, were unproductive, but there was a zone about the edges of these spots where oats, barley, and wheat grew luxuriantly. Many other anomalous things were met with in this section of the state. In some places there were no apparent reasons why crops should not, but they did not grow. In others there was some alkali but the amount of it was less than in others where the crops, not necessarily the same crops, were very good. An analysis of this alkali showed it to be essentially sodic sulfate with some sodic chlorid, about 5.5 per cent of the water soluble, and a relatively large amount of potash with some lime and magnesia. Neither the quantity nor the composition of this alkali affords a satisfactory explanation for the very bad condition of the crops. Only the alkali was collected at this place with as little soil as possible, the idea being that it was probably the composition and not the quantity of the alkali that might be producing the trouble. Twenty per cent of it was soluble in water, and ninety per cent of the soluble consisted of sulfates, six per cent of chlorids and about three and a half per cent of silicic acid, etc. The presence of nitrates was not suspected but subsequently it proved that the water soluble portion gave a strong reaction for nitric acid. This is suggestive only and

not conclusive that nitrates might have been present in sufficient quantity to have caused the poor growth of the barley.

The explanation for the barren condition of these spots seems plain after the analysis of the surface portion of one of them revealed the presence of a little more than 5.5 per cent of nitrates. The suggestion that nitrates might have injured the barley seemed at first almost absurd but the fact that a few grams of earth taken from the surface of the field contained nitrates enough to give a strong reaction for nitric acid with ferrous sulfate removed the absurdity of the idea and indicated that it might have been the case.

Complaints of brown spots "on which nothing will grow" have been common, more so of late years than formerly. This may mean that the spots are becoming more common or that the land having increased in value more attention is paid to them. The former is probably the case as the complaints are coming from different places and often state that alfalfa, for instance, is dying in spots.

The case of a young orchard of 20 acres presents many interesting points. The trees were first set in 1906, in the spring of 1907 many of them were reset especially in a strip beginning at the N. E. corner and running almost directly southwest through the orchard. These trees likewise died and this strip is in no better condition now than it was then. The surface of the ground was brown, not only had the trees died, but all sorts of vegetation. The ground was bare and has continued in this condition till the present time. The surface presented no other points indicative of any abnormal condition, i. e., than the brown color and its total unproductiveness. Had this soil been plowed and harrowed, no one, however proficient in judging of land, even of alkali lands, would for a moment have suspected that this was other than a very desirable piece of land. I have been on this land and could scarcely believe the things that I knew to be facts. The land had been recently disced and it was only by looking rather closely for the signs which I had recognized as suggestive that I could convince myself that the trouble had not disappeared. The one important fact that remained was the presence of dead trees. The death of these trees was not due to neglect or abuse or the lack of any care that good judgment dictated might be needed to make them grow. There was but little or no efflorescence on the surface. There was in some spots a little incrustation, very slight, but this was brown rather than white. For the sake of convenience the surface soil on which this occurred is designated in my notes as efflorescence on brown spot. This spot was barren. There was no free water at a depth of 2½ feet. But below this point the ground was very wet and one could push an auger down for several feet without turning it. This condition

will be described a little later. This sample of surface soil with its incrustation yielded 22.466 per cent soluble in water. We will designate this orchard as No. 1.

ANALYSIS II.

WATER SOLUBLE PORTION OF SURFACE SOIL. Orchard No. 1.

	Per Cent.
Calcic Sulphate	4.462
Potassic Sulphate	2.557
Sodic Sulphate	39.852
Sodic Chlorid	12.626
Sodic Nitrate	29.114
Silicic Acid	0.054
Loss (water, organic matter, etc.)	4.789
	100.000

The sodic nitrate or its equivalent constitutes 6.54 per cent of this surface soil. The first impression, especially in the field, was that salt, sodic chlorid, was the cause of the trouble, but the analysis reveals the presence of another salt which is beyond all question not only more toxic but present in more than double the quantity.

The next sample was taken immediately below the preceding and included the next four inches of soil. The air dried soil yielded 3.4 per cent of salts to water.

ANALYSIS III.

WATER SOLUBLE PORTION OF THE FIRST FOUR INCHES OF SOIL. Orchard No. 1.

	Per Cent.
Calcic Sulphate	11.769
Magnesic Sulphate	3.748
Sodic Sulfate	21.447
Sodic Chlorid	20.797
Sodic Nitrate	32.552
Loss (water, organic matter, etc.)	9.687
	100.000

The organic matter in this sample was very abundant. The nitrates calculated as sodic nitrate equal 1.107 per cent of the air dried soil.

The next sample was collected in a spot occurring in an alfalfa field, belonging to the same party and west of Orchard No. 1. This spot was quite wet, though it had received no irrigation for about five months. The sample was taken in April, 1908, and to the depth of five inches. The air dried material yielded 7.778 per cent of its weight to water. The residue was quite deliquescent. Dried at 110° it smelled faintly acid.

ANALYSIS IV.

WATER SOLUBLE PORTION SOIL FROM ALFALFA FIELD.
West of Orchard No. 1.

	Per Cent.
Calcic Sulfate	21.448
Calcic Chlorid	17.295
Magnesic Chlorid	12.708
Potassic Chlorid	1.641
Sodic Chlorid	6.612
Sodic Nitrate	33.066
Iron and Aluminic Oxid	0.089
Silicic Acid	0.173
Loss (water, organic matter, etc.)	6.968
	100.000

The amount of calcic and magnesic chlorids in this soil is quite surprising. The presence of these salts in a soil extract is quite rare with us. I have met with a few other instances in which these chlorids constitute a considerable portion of the aqueous extract of the soil; in an extreme case it proved that they constituted a little over 55.0 per cent of the aqueous extract; there was in addition to these 25.5 per cent of sodic and 3.8 per cent of potassic chlorid, or a little over 84.3 per cent of chlorids in all. This sample contained a heavy trace of nitric acid but was not collected in Colorado. We will find in this investigation a few samples which carry even larger percentages of calcic and magnesic chlorids than the one whose analysis is given above. The nitrates in this sample constitute 2.571 per cent of the air dried soil. It is remarkable that the surface soil should contain so large an amount of the very soluble nitrates and chlorids considering its wet condition. The alfalfa was dead but the crowns had not yet entirely rotted, indicating that they had died recently and that the present conditions had not obtained for any very long period. The study of conditions in this alfalfa field was not prosecuted further as the orchard presented better conditions for our purposes and it is impossible to study every instance of these conditions which presents itself.

The next sample was taken 60 feet north and west of the first orchard sample, analysis No. II., to a depth of eight inches.

There was no efflorescence or crust on the surface of the soil at this point and also no vegetation. The water soluble portion equalled 1.87 per cent of air dried soil.

ANALYSIS V.

WATER SOLUBLE PORTION, SURFACE EIGHT INCHES.
Orchard No. 1.

	Per Cent.
Calcic Sulfate	14.319
Calcic Nitrate	26.622
Magnesic Nitrate	6.443
Sodic Nitrate	21.277
Sodic Chlorid	25.224
Loss (water, organic matter, etc.)	6.115
	100.000

The nitrates equalled 1.016 per cent of the air dried soil.

Sometimes there is an incrustation, it may be light or heavy, and underneath this there is a mealy mass of soil particles and minute crystals. At other times the surface soil itself is mealy, a peculiar condition which is often expressed by likening the soil to ashes, not always an apt comparison but sometimes an exact description of the condition, especially if the soil is very dry. A sample of mealy soil was taken from this orchard. The soil was slightly incrusted without efflorescence and was mealy beneath the thin crust. The sample was taken to a depth of four inches. The water soluble equalled 5.372 per cent of the air dried soil. The residue was quite deliquescent and smelled acid when dried at 110° for 1 and 3-4 hours.

ANALYSIS VI.

WATER SOLUBLE PORTION MEALY SOIL, FOUR INCHES DEEP.
Orchard No. 1.

	Per Cent.
Calcic Sulfate	19.756
Calcic Chlorid	2.598
Magnesic Chlorid	8.216
Potassic Chlorid	2.117
Sodic Chlorid	27.466
Sodic Nitrate	33.617
Iron and Aluminic Oxid	0.043
Silicic Acid	0.026
Loss (water, organic matter, etc.)	6.161
	100.000

The nitrates constitute 1.706 per cent of the air dried sample.

The next sample represents the foot of soil succeeding the preceding one or from the 5th to 17th inch inclusive. The water soluble equalled 1.161 per cent of the air dried sample.

ANALYSIS VII.

WATER SOLUBLE, 5TH TO 17TH INCH INCLUSIVE.
Orchard No. 1.

	Per Cent.
Calcic Sulfate	27.456
Magnesic Sulfate	11.245
Potassic Sulfate	2.753
Sodic Sulfate	1.688
Sodic Carbonate	2.255
Sodic Chlorid	29.712
Sodic Nitrate	19.431
Iron and Aluminic Oxid	0.089
Silicic Acid	1.052
Loss (water, organic matter, etc.)	3.319
	100.000

The section of this soil showed alternations of light and dark sandy loam. The nitrates constituted 0.226 per cent of the air dried sample.

The next sample represents the succeeding foot or from the

18th to the 29th inch inclusive. The water soluble was 2.11 per cent.

ANALYSIS VIII.

WATER SOLUBLE, 18TH TO 29TH INCH INCLUSIVE.
Orchard No. 1.

	Per Cent.
Calcic Sulfate	49.413
Magnesic Sulfate	20.202
Potassic Sulfate	0.670
Sodic Sulfate	0.923
Sodic Carbonate	2.556
Sodic Chlorid	12.487
Sodic Nitrate	9.375
Sodic Silicate	1.371
Manganic Oxid (br)	0.141
Loss (water, organic matter, etc.)	2.862
	100.000

The nitrates in this sample which represents the lower 3-4 of the second and the first 1-4 of the third foot from the surface constitute 0.198 per cent of the air dried soil. This is the deepest soil sample taken in the orchard.

The ground water in this orchard cannot be said to present a water plane. The soil is very wet at a depth of two and a half feet and forms a real mud from this point downward, but at a depth of six feet the water came in so slowly that in order to fill a two gallon jug we had to let the hole stand open over night. A little water came in at a depth of five feet but this seemed to be an accident, for the next foot below was the same as above, simply mud. I had never seen anything similar to this condition before I began to study this subject. What the relation may be between these facts I do not know; according to what is generally believed they are more or less incompatible but they are simply facts. It is surprising that soil can be so wet and muddy for 3½ feet and we should be unable to find a proper water table within six feet of the surface, but, as stated, we were compelled to let the opening stand over night in order to obtain the sample of ground water. The ground water as obtained was slightly yellow; the total solids held in solution were 1776.05 grains per imperial gallon; loss on ignition 453.42 grains. A part of this loss is due to the presence of nitrates and is more interesting than important, because on ignition the evolution of the brown oxids of nitrogen was quite copious. This water contained 2.0 parts per million of nitrogen as nitrites. ordinary polluted water contains 0.003 parts per million.

ANALYSIS IX.

RESIDUE FROM GROUND WATER. Orchard No. 1.

	Per Cent.
Calcic Sulfate	15.164
Magnesic Sulfate	9.890
Magnesic Cholrid	11.358
Sodic Chlorid	7.225
Sodic Carbonate	1.825
Sodic Nitrate	53.299
Potassic Oxid	Trace
Iron and Aluminic Oxid	0.372
Silicic Acid	0.061
Loss (water, organic matter, etc.)	0.906
	100.000

This residue containing 53.3 per cent of sodic nitrate gives us 941.0 grains of this salt to each imperial gallon. As iodine compounds sometimes occur associated with the nitrates, I tested this residue, using 30 grams, but obtained negative results.

This gives us an idea of the conditions obtaining in this orchard which may be summarized as follows: The surface soil has a brownish color, efflorescent salts are scarcely present. There is some incrusting of the surface soil, beneath which there is sometimes as much as an inch of mealy material, soil particles and fine crystals. At a depth of two to two and a half feet the ground becomes muddy, but there is no free water to a depth of 5½ to 6 feet. There is no vegetation on parts of this ground and the young trees have failed to live. The country is quite flat but is not particularly low; it probably is not less than 50 feet above the river which flows within four miles of it. We find an abundance of nitrates in the uppermost portion of the soil, the maximum being 6.541 per cent of the soil; this soil was incrusted with some efflorescent salts, commonly called alkalis. The next, a sample of very wet soil taken to a depth of five inches, gave 2.571 per cent of nitrates. These percentages are followed by 1.706, 1.107 and 1.016, for what we may consider the first foot of soil, with 0.226 for the upper portion of the second foot and 0.198 for the rest of the soil to the depth of 29 inches.

In the next orchard which I shall designate as Orchard No. 2, we have the same conditions only greatly intensified. This is an older orchard, what is left of it, and we can see the effects more plainly than in Orchard No. 1. What was once an orchard is now absolutely barren, not so much as a weed growing on several acres of this land. See Plate II. There are a few trees remaining in one corner and a few isolated trees on one edge. These will have a great interest for us. The first samples from this orchard were taken in 1907. The soil was glistening, brown and apparently wet on the surface but was really dry. Mr. Whipple who was with me dug a hole close to a small apple tree which was already

so good as dead. No water was met with at a depth of three feet; the soil was wet but not sufficiently so to drown the tree; at this place the soil was somewhat sandy. An excavation had been made, but not recently, for the cellar and foundations of a house, this excavation was over three feet deep but contained no water. This was a surprise to us at the time, especially as we had found the soil only a short distance away so wet. Six months later we found the conditions essentially the same; except worse if anything. There were portions of the ground on which there was a crust about 3-16 of an inch thick and beneath this from 1½ to 3 inches of the mealy mixture of soil and crystals. Below this the soil was practically mud, but, as in Orchard No. 1, we had to dig to a depth of six feet in order to obtain a sample of ground water. The crust in this case was not the ordinary crust of effloresced salts accumulated above and easily separated from the soil, but was the soil particles cemented together by the salts present in it. This crust contained 12.523 per cent soluble in water.

ANALYSIS X.

WATER SOLUBLE PORTION OF CRUST. Orchard No. 2.

	Per Cent.
Calcic Sulfate	8.523
Calcic Chlorid	27.388
Magnesic Chlorid	25.875
Potassic Chlorid	1.581
Sodic Chlorid	16.511
Sodic Nitrate	19.822
Iron and Aluminic Oxid	0.223
Silicic Acid	0.077
	100.000

This analysis has been calculated to 100 because on drying the mass I found that I could not heat it above 110° C. without change and at 110° only a part of the water was driven off. It was therefore necessary to analyze the material as it was and calculate the results to 100 as I have done. The nitrates make up 1.482 per cent of the air dried soil.

The next sample was taken to a depth of 1½ to 3 inches below the crust given above. The water soluble portion equalled 8.44 per cent. The following analysis has been computed to 100 for the same reason given for the preceding analysis.

ANALYSIS XI.

WATER SOLUBLE PORTION OF MEALY SOIL. Orchard No. 2.

	Per Cent.
Calcic Sulfate	15.058
Calcic Carbonate	1.755
Calcic Chlorid	23.158
Magnesic Chlorid	25.532
Potassic Chlorid	1.667
Sodic Chlorid	17.014
Sodic Nitrate	15.421
Iron and Aluminic Oxids	0.139
Silicic Acid	0.265
	100.000

The nitrates constitute approximately 1.301 per cent of the air dried mealy soil.

The next sample was taken from another part of the orchard about six months prior to the taking of the two preceding samples and shows in an unusual measure the variability in the character of the salts present in the soil. The area involved is several acres. I suppose that there are 40 acres at least in this piece of land but I do not know how much of it is involved in this trouble. I estimate the portion that I am familiar with at 10 or 12 acres and very much more in adjoining lands. This sample was taken to a depth of one foot. Water soluble equalled 6.51 per cent. The ground is entirely barren where this sample was taken..

ANALYSIS XII.

WATER SOLUBLE PORTION OF FIRST FOOT OF SOIL. Orchard No. 2.

	Per Cent.
Calcic Sulfate	13.072
Magnesic Sulfate	4.928
Sodic Sulfate	7.691
Sodic Chlorid	27.609
Sodic Nitrate	43.578
Loss (water, organic matter, etc.)	3.122
	100.000

The nitrates in this foot of soil amounted to 2.837 per cent of its air dried weight. This indicates the presence of 49.5 tons to the acre foot.

This soil is very wet except the surface portion to a depth of three or four inches, below this point it becomes muddy; even worse if anything than Orchard No. 1. At a depth of about six feet water came into the hole that we dug, very slowly. We were able to get two gallons of water in about an hour. This water contained 2250.01 grains per imperial gallon; the loss on ignition was 375.5 grains.

ANALYSIS XIII.

RESIDUE FROM GROUND WATER. Orchard No. 2.

	Per Cent.
Calcic Sulfate	22.077
Magnesic Sulfate	14.405
Magnesic Chlorid	0.833
Potassic Chlorid	0.441
Sodic Chlorid	44.492
Sodic Carbonate	1.741
Sodic Nitrate	10.545
Iron and Aluminic Oxids	0.256
Silicic Acid	0.067
Loss (water, organic matter, etc.)	5.143
	100.000

Each imperial gallon of this ground water contains 237.0 grains of sodic nitrate. The ground water from Orchard No. 1 contained 941 grains, almost exactly four times as much.

The next place studied included both orchard and non-orchard land, but for the sake of convenience we will designate it as Orchard No. 3.

This is, in some respects, the most interesting case that I have studied because I have been able to obtain its history. The land showed some spots 17 years ago on which there appeared to be too much alkali. Some of the spots grew nothing but at their outer edges things grew well. The owner stated that he had often stood on a barren spot and thrown his hat in the air so that it would fall on the grain at the edge of the spot and lodge on the heads of the grain. This man had tried to wash it off; he had turned a furrow, followed with a subsoil plow and then turned in a hundred inches of water and washed it clean. His farm is beautifully leveled. He had also manured heavily but he has not yet conquered these spots. He states that in the 16 or 17 years past he has set one piece to young trees two or three times and there are no living trees there now. In June, 1908, I took a set of samples from this piece of ground. The top three inches is described as alkali and mealy soil. This three-inch section was removed and taken as one sample. Water soluble equalled 5.04 per cent.

ANALYSIS XIV.

WATER SOLUBLE PORTION OF ALKALI AND MEALY SOIL. Orchard. No. 3.

	Per Cent.
Calcic Sulfate	14.247
Magnesic Sulfate	4.464
Potassic Sulfate	2.459
Sodic Sulfate	6.849
Sodic Chlorid	33.607
Sodic Nitrate	35.582
Silicic Acid	0.208
Loss (water, organic matter, etc.)	2.584
	100.000

Here the nitrates equalled 1.793 per cent of the air dried weight of the mass.

After removing the three inches of alkali and mealy soil, I took the next 12 inches as a soil sample. The water soluble amounted to 2.97 per cent of the air dried material. This spot had been barren for 16, now 18, years. I saw it a few weeks ago and it is barren still.

ANALYSIS XV.

WATER SOLUBLE, 4TH TO 15TH INCH INCLUSIVE. Orchard No. 3.

	Per Cent.
Calcic Sulfate	15.902
Magnesic Sulfate	2.942
Potassic Sulfate	3.387
Sodic Sulfate	15.264
Sodic Carbonate	4.813
Sodic Chlorid	34.145
Sodic Nitrate	22.781
Silicic Acid	0.252
Loss (water, organic matter, etc.)	0.471
	100.000

The nitrates in this sample equalled 0.676 per cent of the air dried material. I subsequently dug a hole in this piece of ground at the height of the irrigating season, not at this same spot but near it, to see if I could find the water table. I dug to a depth of six feet and found only moist, sandy soil.

The next sample was taken by the owner and sent to me. He stated it was taken from another barren spot and to a depth of one foot. Water soluble equalled 3.33 per cent of air dried soil.

ANALYSIS XVI.

WATER SOLUBLE PORTION OF FIRST FOOT OF SOIL. Orchard. No. 3.

	Per Cent.
alcic Sulfate	5.459
agnesic Sulfate	1.086
otassic Sulfate	2.557
odic Sulfate	49.269
odic Carbonate	2.285
odic Chlorid	23.897
odic Nitrate	11.762
licic Acid	0.111
oss (water, organic matter, etc.)	3.583
	100.000

The nitrates make up 0.392 per cent of the air dried soil in his case. This is one of the spots in which the owner amused himself by standing and casting his hat in the air to see it fall on the grain so rank and stiff-stemmed that it held up the hat.

The next sample is one taken by myself in an alfalfa field on the same ranch. The spot was quite wet and barren. Sample taken three inches deep. Water soluble equalled 10.572 per cent.

ANALYSIS XVII.

WATER SOLUBLE, FROM ALFALFA FIELD. Orchard No. 3.

	Per Cent.
Calcic Sulfate	6.968
Magnesic Sulfate	6.490
Potassic Sulfate	2.526
Sodic Sulfate	45.168
Sodic Carbonate	1.513
Sodic Chlorid	26.116
Sodic Nitrate	4.056
Silicic Acid	0.458
Loss (water, organic matter, etc.)	6.705
	100.000

The next sample is from another orchard, Orchard No. 4. Had the owner not set this land to apple trees the probabilities are that no notice would have been taken of the fact that there was something wrong with the soil. The care bestowed on a young orchard is greater perhaps than that bestowed on ordinary crops. This accounts for the fact that we find these troubles so frequently in apple orchards; it is not that they do not exist elsewhere, for they do. This young orchard contained, it may be, 20 acres, sloping to the south and west. The land is quite high. Some years ago there was a reservoir in the northeast corner of this piece of ground but it had been abandoned for several years, at least four, before the orchard was set. The soil is a clayey loam, but varies somewhat in different parts of the tract. A shale underlies the whole or the greater portion of it at no considerable depth. There is a little draw running southwest and south through the orchard. It begins near the north side and somewhat east of the middle line and extends almost to the southwest corner of the orchard. The area involved in the spring of 1909 was about four acres. By autumn it had increased to nearly double or about eight acres. The land had previously been in alfalfa which, according to my infromant, had ceased to do well in this portion of the field. Up to this time only preliminary work has been done on this particular orchard and it is given for the reason that it presents entirely different conditions from any presented so far. In March, 1908, I found the surface soil a mealy mass. The conditions at the time did not afford opportunity for me to judge of the color of the soil. There was no incrustation; a scuff with the foot would reveal the fact that the dirt which seemed to be ordinary soil was a mixture of soil and crystals of some sort, for they glistened strongly in the light, and clear sunshine was not necessary. I took a sample to a depth of two inches. The water soluble was 8.23 per cent of the air dried mass.

ANALYSIS XVIII

WATER SOLUBLE FROM SURFACE SOIL. Orchard No. 4.

	Per Cent.
lcic Sulfate	18.986
gnesic Sufate	29.771
tassic Sulfate	1.387
dic Sulfate	39.914
dic Chlorid	1.474
dic Nitrate	8.173
icic Acid	0.295
	100.000

The nitrates make up 0.673 per cent of the air dried mass. The sults of this analysis were what I expected after I had examined e conditions in the orchard.

The next sample is our Laboratory No. 680, and is not from orchard but from an oat field. The owner had previously itten to me concerning this land. I could not go to inspect it the time but in February, 1908, I was near this place and went see it. The chief trouble was seepage, but above the seeped area ere other conditions, the surface of the ground was puffed up d mealy. I took a sample of the surface soil to a depth of two ches, water soluble equalled 5.42 per cent. I was compelled to y the residue obtained on evaporating the aqueous extract to yness at 140° in order to pulverize it; it puffed up, intumesced, d possibly suffered incipient decomposition.

ANALYSIS XIX.

WATER SOLUBLE PORTION. Laboratory No. 680.

	Per Cent.
lcic Sulfate	9.919
lcic Nitrate	10.053
gnesic Nitrate	17.290
tassic Nitrate	1.159
dic Nitrate	21.719
dic Chlorid	38.179
n and Aluminic Oxids	0.129
icic Acid	0.093
ss (water, organic matter, etc.)	1.459
	100.000

The nitrates in this surface sample equalled 2.722 per cent the air dried soil; this is a trifle over 50 per cent of the total luble salts. It may interest someone to learn that I visited this ace in the early spring of 1909 and could see no signs of any ouble whatsoever beyond the fact that a portion of the field was doubtedly seeped. I visited it again later and the present owner no is a stranger to me, was cultivating it preparatory to planting to beets and there was nothing suspicious, even to one acquainted ith the facts, except the seepage. I visited it again when the ets were almost ready to harvest. There were great bare spots

surrounded by beet tops of very luxuriant growth. See Plate V The bare ground was mealy and excessively rich in nitric acid or n trates. We must defer further statements concerning this till w have done more work.

Our Laboratory No. 588 is a very alkaline soil collected in a old orchard. The soil is a red mesa soil, grows alfalfa, potatoe wheat, etc., well. The section is in very bad condition and seep though the mesa is high above the river. The surface of the me makes this possible. The water soluble in this soil was 6.65 p cent.

ANALYSIS XX.

WATER SOLUBLE PORTION. Laboratory No. 588.

	Per Ce
Calcic Sulfate	20.1
Magnesic Sulfate	6.5
Sodic Sulfate	38.8
Sodic Chlorid	23.7
Sodic Nitrate	4.0
Potassic Nitrate	1.7
Sodic Silicate	0.5
Loss (water, organic matter, etc.)	4.3
	100.0

The nitrates correspond to 0.382 per cent of this soil.

The next sample is Laboratory No. 595, and was gathered a sample of alkali. The spot was quite destitute of vegetation e cept for the presence of a few greasewood, sarcobatus plants, and few surviving alfalfa plants. I have visited this place twice since th sample was collected to observe whether the spot is increasing size. I found this to be the case. Only so much of the soil w taken as was necessary to get a fair sample of the surface alka perhaps an inch. This was a new locality for alkali, so far as r record was concerned and the sample was taken without any rega to the presence or absence of nitrates; it was collected in 1907.

ANALYSIS XXI.

ALKALI. Laboratory No. 595.

	Per Ce
Calcic Sulfate	9.1
Magnesic Sulfate	8.0
Sodic Sulfate	56.2
Sodic Chlorid	22.6
Sodic Silicate	0.3
Sodic Nitrate	2.7
Loss (water, organic matter, etc.)	0.8
	100.0

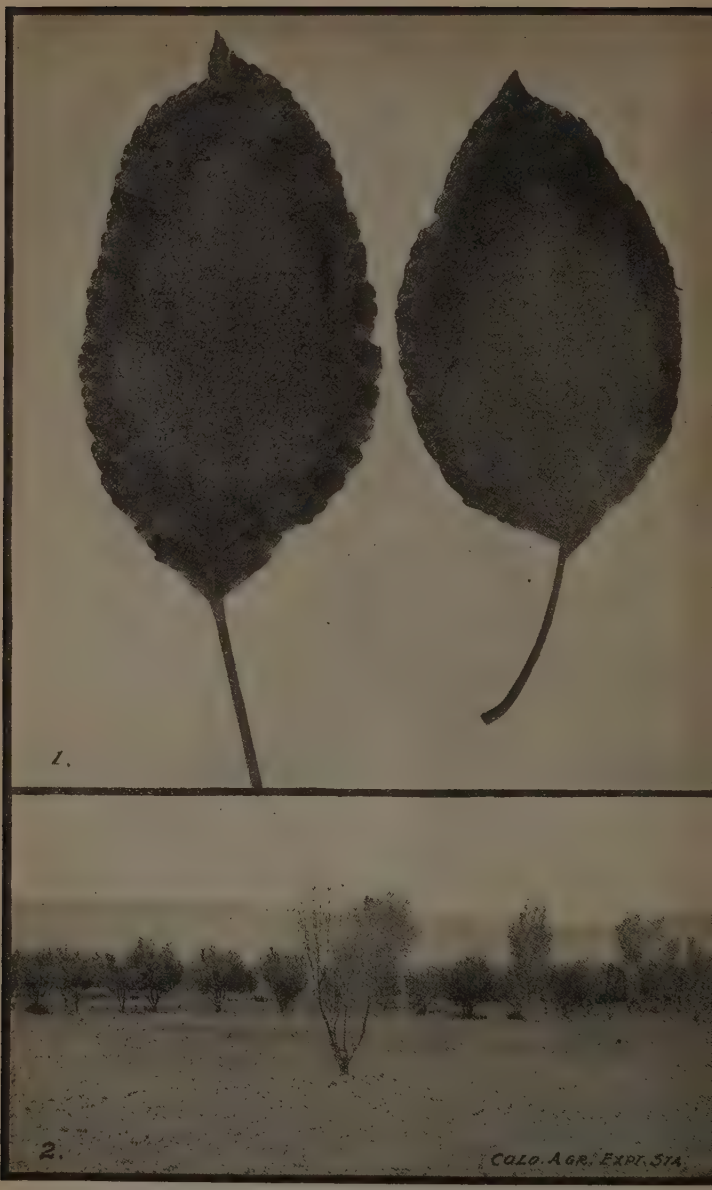
The question of the relation of the greasewood to the alk question, sodic carbonate in particular, has been discussed son what by Prof. Hilgard and others. The association of this pla with the last sample suggests the question whether it might ha anything to do with the appearance of the nitric acid in this alk

some cases there is no question about the occurrence of sodic carnate in dark soils about old clumps of greasewood, but in this se the occurrence of the nitrate in dark, brown soils and the very rk color often noticed in the soil about these old clumps suggests e question whether the greasewood has anything to do with this currence. I found a very marked case of a mass of dark soil where ch a clump had died and which was evidently very rich in alkali. his was quite near an area where I knew that nitrates occurred large quantities so I thought it worth while to test the matter. he result was that the soluble salts found to be present were the lfate 35.248 per cent, carbonate 37.065 per cent, and chlorid of dium 27.687 per cent, with only a trace of nitric acid. This was e result expected except that the trace of nitric acid was unlooked r under the conditions. Apropos to the occurrence of nitrates alkalis we have found small quantities of nitrates in others than e one given above but we have not found them always present. lkalis from these districts may be entirely free from nitrates.

The samples so far given have been of soils or ground waters, e localities of which I have not given and I have purposely avoid- giving names. I conceive that the circumstances require that I ould do this. I have been requested again and again not to pub- h the names of owners and places and I believe that it is just at I should not, for while it looks, in many cases, desperate for e future, conditions may change. Some means of remedy may found whereby what now seems an inevitable result may be oided.

I have seen instances of these occurrences of nitrates near the uthern and within 40 miles of the northern boundary of Colorado d likewise from its eastern to its western boundary. The analyses ready given and those to be given, represent many sections, but it not to be inferred that all or any more than a very small perntage of the agricultural lands of Colorado are in the least enngered. While the matter is serious enough, it by no means nounts to a justification for evil forebodings. I am not at this me prepared to state how we will combat this condition, but I lieve that there will be some way. These remedial questions are r the immediate future; the trouble itself has, as yet, only been inted out.

I will give some cases in a general way but must avoid names d places. A small piece of land, a sandy loam, near and some or 15 feet above the river has a dark brown color and has not en productive for several years. This land has received good ltivation, the application of much barnyard manure, and excessive rigation in the hope that the "black alkali" would be washed out. his ground is not absolutely barren but some spots in it are nearly



Plates I and II. See Pages 6, 13; 42, 43 and 44.

so. A sample of this soil which was taken by the owner and delivered to me contained 1.262 per cent of water soluble which contained nitric acid equivalent to 11.230 per cent of sodic nitrate, equivalent to 0.142 per cent of the air dried soil. If this sample had been taken to a depth of a foot, which it very probably was, how much would it mean to the average man? Very little so long as it is expressed in tenths of one per cent of the soil. It will mean more to him, perhaps, if we state that this is a piece of very bad land containing 5,680 pounds, 2.84 tons, of sodic nitrate or its equivalent of nitric acid in the top foot of soil. I found on this piece of land an excellent illustration of the mealiness which I have already mentioned several times. The adjoining piece of land on the north is in even worse condition than this, spots in it are barren.

Another case was observed in an alfalfa field under and near a ditch. We are prone to blame seepage for as many of our troubles as possible and I am personally no exception, but I am sometimes conscious that I am trying to give a reason to avoid the labor of finding out a cause. In this spirit I judged the cause of the dead spots in this alfalfa to be due to seepage. The ditch was there; there was water enough; the ditch was higher than the ground. Of course it was simply another case of seepage. I, however, thought it might be well to prove this thing. On examining the ground and digging a hole of some depth my faith in my theory disappeared. I was not at all satisfied about the relation of seepage to the death of the plants. I took a sample of the soil and found that 5.73 per cent of its weight was soluble in water and that this soluble part contained nitric acid corresponding to 27.259 per cent of sodic nitrate or calculated on the air dried soil 1.522 per cent or supposing this soil to have been taken to a depth of four inches it means that there would be 20,290 pounds, 10 1-4 tons, on each acre. If one should spread 10 1-4 tons of Chile-saltpetre on an acre of ground we would not need to appeal to seepage to account for any unproductiveness of the soil which might follow. After a number of such experiences I have concluded that it is not wise to be too certain about the direct and universal effects of seepage. The same remark applies to the effects of alkali. I am quite convinced that I have not seen in Colorado a single instance in which it was even very probable that our ordinary alkali, not this so called "black alkali," has of itself been the cause of the death of any plant. An excess of water in the soil, especially in cases where it continued for a long time, may have been.

These occurrences are not confined to Colorado soils. Two samples of soil received from Brawley, California, were strongly impregnated with alkali and their aqueous extracts reacted for nitric acid with sulfuric acid and ferrous sulfate. Neither the size nor lo-

cation of the spots relative to the surrounding surface nor the condition of the vegetation was given. The clumps of one of the samples showed distinctly a thin, white incrustation on their upper surfaces. The sample was quite sandy and judging from the clumps of soil had been taken to a depth of from one to two inches. The second sample was quite different in character and described by the sender as being always moist.

The sample numbered one and described as white alkali soil contained 8.886 percent of water soluble salts. The nitric acid in this soluble portion corresponded to 3.939 percent of sodic nitrate or 0.350 percent of sodic nitrate calculated on the air dried soil. This corresponds to 2,333 pounds of sodic nitre in the surface two inches of soil per acre. I do not know anything about the size or location of the areas represented, nor do I know the condition of the vegetation in or about the places where the samples were collected.

One of the samples was a sandy soil and was very probably taken to only a very shallow depth. The sender says that it was scraped up. I would judge from the thickness of the clumps in the sample that from one to two inches of the surface soil had been taken.

We find the nitrates present in soils, where there is a great deal of moisture, but in places where there is too much water, the nitre does not appear. In little valleys and saucer shaped depressions in which the lower portions are too wet there is no visible alkali, then follows a zone where white alkali abounds and above this the nitre is formed. I do not mean to say that there may not be nitre mixed with the white alkali but that the nitre in such cases appears in higher ground than that on which the white alkali usually appears. Furthermore, it is not intended that anyone shall infer that it is only in valleys and depressions that the nitre occurs. Two instances of the occurrence of nitre suggest themselves, one of which is on the side of a hill, and the other on a little reach of rising land at the foot of a hill. It is at least 10 feet higher than land 200 yards away, in short, it is on the gently sloping portion of a hill. These two instances are very far removed from any other occurrences so far mentioned and are nearly 300 miles apart. These occurrences are furthermore very rich in nitrates.

The next sample is an alkali collected from the face of a shale bank from which issued the seep or drainage from an irrigated mesa. The water issuing from this bank contained 176.96 grains total solids per imperial gallon, ignition 21.42 grains. There are no carbonates present. The efflorescent alkalis on this shale bank were white and consisted essentially of magnesic and sodic sulfates, but carried about 2.3 per cent nitrates.

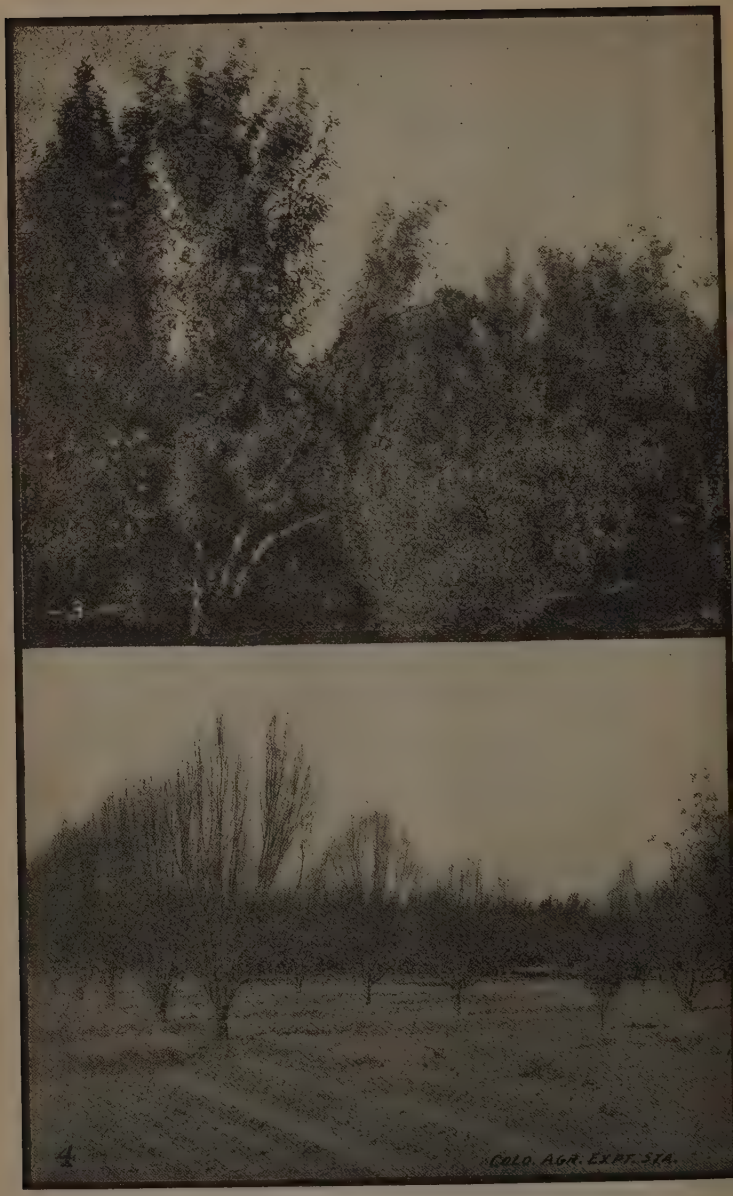
The last sample naturally suggested the examination of other waters issuing from the shales underlying irrigated mesas. The same point had been reached, starting from an entirely different point of departure, i. e., the search for an answer to the question, how much alkali may an irrigation water contain without detriment to the land to which it is applied? No attempt is made to answer this question at this time; it suffices that no one has yet complained with good cause that he has reached the injurious limit. An inspection of the next two analyses will indicate clearly why they are given in this place. The land was planted to corn and rye. It had passed into the hands of a man who had no experience with irrigation; the water was handy and plentiful, the people on the mesa above had only a moderate supply of water or there would have been more. The corn had been rather deeply furrowed for the purposes of irrigation. There was a band of efflorescent alkalis at least two inches wide on the side of each furrow. My curiosity was excited to find some reason why the corn should grow at all and not die. The rye was dying, but the corn was in pretty fair condition, which was a matter of surprise. Inquiry elicited the fact that small stuff had been a failure on this ground. I took a sample of the worst of this surface soil where even the corn, which seemed to have endured better than anything else, had almost failed. The irrigation was very excessive. The sample of soil yielded 4.67 per cent of water soluble, which gave me the following analysis: The determination of NO was made four times, because at the end of the reaction there was a rather copious evolution of CO_2, more than the sodic hydrate in the measuring tube could readily absorb.

ANALYSIS XXII.

WATER SOLUBLE PORTION. Laboratory No. 589.

	Per Cent.
Calcic Sulfate	16.645
Magnesic Sulfate	14.518
Potassic Sulfate	2.360
Sodic Sulfate	35.731
Sodic Chlorid	19.914
Sodic Nitrate	7.352
Sodic Silicate	0.328
Loss (water, organic matter, etc.)	3.152
	100.000

The nitrate according to this analysis is 0.342 per cent in this portion of the soil. This can only be considered as an approximate result. The big fact is that nitrates were present in notable quantities. This land was irrigated with the seepage water which issued from or above the shale underlying the mesa. This water contained 418.2 grains per imperial gallon or 5,975.7 parts per million. No nitrites were present.



Plates III and IV. See Pages 42 and 44.

ANALYSIS XXIII.

RESIDUE FROM SEEPAGE WATER. Laboratory No. 766.

	Per Cent.
Calcic Sulfate	27.397
Magnesic Sulfate	27.697
Potassic Sulfate	1.389
Sodic Sulfate	21.749
Sodic Carbonate	4.026
Sodic Chlorid	5.391
Sodic Nitrate	2.986
Sodic Silicate	0.401
Loss (water, organic matter, etc.)	8.944
	100.000

These two samples are more interesting in connection with this work than in connection with the purpose for which they were collected. Results like the foregoing are very disconcerting when one is seeking the limit of alkalis present in an irrigation water which may be injurious to the land or crops. The same is true in regard to the soil. It is true that this sample represented what I believed to be the worst and what according to the growth of the corn, was the worst, but the whole patch was so bad that it appeared useless to continue that study with great hope of success. The only encouragement that one could find in the case was that some things had died and that the rye was dying, but the question whether this was due to excessive salts or excessive water was impossible to determine. This digression may serve to show that our problems are far from simple and that an acquaintance with a large range of facts pertaining to our conditions does not lead to very firmly fixed convictions concerning what the facts really may be. I will add one more statement relative to this piece of ground and that is, that I saw the wheat grown on it two years later, 1900, and it yielded at the rate of 60 bushels per acre. All of which was extremely perverse from the standpoint of the theorist but very good from that of the owner.

The question of the presence of nitrates in seepage water issuing from the shales seemed to be of sufficient interest to justify further analyses. Another place was selected 80 feet below the top of the bank which was the level of the mesa. The sample was taken in the irrigating season. The water contained 557.9 grains per imperial gallon or 7,970.0 parts per million of total solids; ignition expelled 84.9 grains or 121.3 parts per million. This water was tested for free ammonia and 0.12 part per million was found. The following analysis has been calculated to one hundred.

ANALYSIS XXIV.

RESIDUE FROM SEEPAGE WATER. Laboratory No. 739.

	Per Cent.
Calcic Sulfate	31.102
Magnesic Sulfate	26.487
Potassic Sulfate	1.210
Sodic Sulfate	21.305
Sodic Carbonate	6.101
Sodic Chlorid	8.531
Sodic Nitrate	4.972
Sodic Silicate	0.292
	100.000

The aggregate volume of water issuing from a long stretch of this shale is large and according to this analysis each gallon of 70,000 grains carries 27.75 grains of nitrates.

In looking for a place to take a sample of shale to see whether the shale itself carried nitrates a brick yard offered the best opportunity for here a face, which had been recently opened, was accessible. The overlying strata are thin but the mesa country above and back of this opening is very extensive and quite well watered. It was observed that the brick in the drying sheds were covered with an efflorescence. This consisted essentially of sodic sulfate about 88.0 per cent; nitric acid was present but was not determined. A sample of the shale 1,280 grams was extracted with water and yielded 1.4 per cent of material soluble in water.

ANALYSIS XXV.

WATER SOLUBLE PORTION OF SHALE. Laboratory No. 645.

	Per Cent.
Calcic Sulfate	32.198
Magnesic Sulfate	13.705
Potassic Sulfate	1.930
Sodic Sulfate	42.990
Sodic Carbonate	0.716
Sodic Chlorid	2.477
Sodic Nitrate	1.711
Sodic Silicate	1.081
Loss (water, organic matter, etc.)	3.192
	100.000

The nitrates calculated on the air dried shale gives 0.03 per cent. The shale presents but little of interest. The amount of nitric acid found is so small that it would escape detection in the ordinary course of analysis. Still the analysis of this shale was made and shows that there is nothing in the character of the shale itself to indicate anything unusual.

ANALYSIS XXVI.

ANALYSIS OF SHALE. Laboratory No. 645.

	Per Cent.
Carbon	1.587
Silicic acid	47.292
Sulfuric acid	1.457
Carbonic acid	11.466
Chlorin	0.053
Titanic acid	0.500
Calcic oxid	16.129
Magnesic oxid	2.271
Potassic oxid	2.389
Sodic oxid	2.884
Ferric oxid	4.052
Aluminic oxid	7.957
Water at 108°	1.699
Water at 200°	0.656
	100.392

This shale is fossiliferous, is low in silicic acid and carries a large amount of lime, but no organic matter or other source of nitric acid.

We have presented by a considerable number of samples, the question of the nitrates in the soil, in the ground waters and in some of our seepage waters. There yet remains the question of our drain waters. We have but two of these to present. One is from a water course constituting the natural drainage of the section in which it is located, the second is from a box drain laid 4½ feet deep.

The water course constitutes what is locally called a "wash." The sample was collected in October, 1907, and was made up of a mixture of water from the irrigating canal, of off flow water from irrigated fields, and of seepage or drain water. The total solids were 359.52 grains per imperial gallon or 5,164.5 parts per million; ignition expelled 115.08 grains. This wash runs through the first mesa counting from the river and the mesa back of this has not yet been brought under irrigation. The depth of soil over the shale is not great, in some places it is very shallow.

ANALYSIS XXVII.

RESIDUE FROM WASTE WATER. Laboratory No. 605.

	Per Cent.
Calcic Sulfate	20.283
Magnesic Sulfate	33.573
Sodic Sulfate	20.749
Sodic Carbonate	5.351
Sodic Chlorid	8.528
Sodic Nitrate	4.159
Sodic Silicate	0.631
Sodic oxid (excess)	0.161
Loss (water, organic matter, etc.)	5.346
	100.000

Plates V and VI. See Pages 20, 43, 44 and 45

I do not know how much water was flowing in this stream at time the sample was taken. Nor do I know how much the rage flow of this stream may amount to. I imagine that the v varies greatly from time to time.

The next sample is one of a drain water taken in Oct., 1907. s drain was one of the main branches of a system put in 6½ rs prior to the taking of the sample for the purpose of improving iece of ground lying to the east and south and partly to the west a rather large orchard. In spite of the drain the bad soil con-ons have encroached upon the orchard area necessitating the re-val of trees till the orchard is much smaller than it was six years . The case of this orchard is rather peculiar. There is on the th and west sides of the orchard a wash ranging from 6 to 10 deep and on the east, south and part of the west side is this em of drains and yet in June of this year I saw some of the remaining trees in the extreme southern portion of the orchard y badly burned by nitre. The drain is a box one, seven by six ies laid 4½ feet deep. The land above the orchard was boggy ne time the drain was laid. It has been unwatered to the extent grain can be grown on the greater portion of the land. The d on some parts of this land is excellent. The condition of the ard as suggested is gradually becoming worse and is at this e a promising subject for study. Total solids 637.3 grains per erial gallon.

The analysis has been calculated to one hundred.

ANALYSIS XXVIII.

RESIDUE FROM DRAIN WATER. Laboratory No. 610.

	Per Cent.
c Sulfate	23.203
nesic Sulfate	36.662
ssic Sulfate	0.705
e Sulfate	29.991
e Chlorid	2.863
e Carbonate	4.093
e Nitrate	2.275
ic Acid	0.209
	100.000

The residue gave off water and red fumes when heated in a tube. A sample of this drain water taken in June, 1909, about months later, showed the presence of 622.65 grains of total ls per imperial gallon. Loss on ignition was 99.26 grains per erial gallon. The ammonia was found to be 0.56 part per mil-

The analysis has been calculated to one hundred.

ANALYSIS XXIX.

RESIDUE FROM DRAIN WATER. Laboratory No. 792.

	Per Cent
Calcic Sulfate	22.35
Magnesic Sulfate	31.58
Potassic Sulfate	1.50
Sodic Sulfate	24.77
Sodic Chlorid	9.05
Sodic Carbonate	4.12
Sodic Nitrate	6.50
Silicic Acid	0.11
	100.00

These results show what is pretty well demonstrated by the other samples, i. e., that the presence of the nitrates in the waters is not an accidental but a regular occurrence.

I have now presented all of the analytical data which I propose to present in this bulletin to show the occurrence of excessive amounts of nitrates in certain of our soils. These occurrences are not confined to one section of the state; the samples given represent widely separated sections.

There are no data that I have been able to find relative to the amount of nitric acid, respectively nitric nitrogen, in soils in general. The most satisfactory statements have been found in the latest edition of Storer's "Agriculture." These statements are largely based on the Rothamsted experiments and give aggregate results which are very difficult to apply to our lands, or to use in answering the questions suggesting themselves. We, therefore, collected a number of samples, representing the surface portion of our soils, because it is only with the upper layers that we are concerned. The percentages of nitrates given in the preceding analyses varying from 0.2 to upwards of 5.0 per cent of the air dried samples will not appeal to some readers as large quantities, therefore we wish to know and present what some other surface soils in Colorado contain. We are aware that the content of nitric nitrogen in a soil varies from time to time and that the nitrates may be carried down to considerable depths by rain water, etc.; all of these things have but little bearing on the object had in view. We wanted to know how much nitric nitrogen we might expect in the soil to a depth of 2½ feet, for our samples have mostly been taken at less depths, in fact the most remarkable quantities have been found practically within the first half inch of soil, though some very large percentages have been found at as great depths as three inches. We determined on sampling different sections of the College farm. The samples were taken in October during a period of fine weather and no irrigation water had been applied for some weeks. Other detailed data of this character are not at my disposal. This study was entrusted to Mr. Douglass and the following is his report:

SAMPLES TAKEN TWO INCHES DEEP.

	Per Cent Nitric Nitrogen		
	Oct. 4	Oct. 6	Oct. 16
S. of Agr'l Hall near N. end of grain field	0.00045	0.00040	0.00035
S. of Agr'l Hall near S. end of grain field	0.00085	0.00120	0.00035
S. of Agr'l Hall near W. side of grain field	0.00050	0.00040	0.00010
Beet field, Experimental Farm	0.00005	0.00005	0.00005
Unused roadway, near beet field	0.00500	0.00350	0.00100
Alfalfa plot, fallow place		0.00225	.....
Beet field, fallow place		0.00120	.....

SAMPLES TAKEN THREE INCHES DEEP.

October 7, 1909.

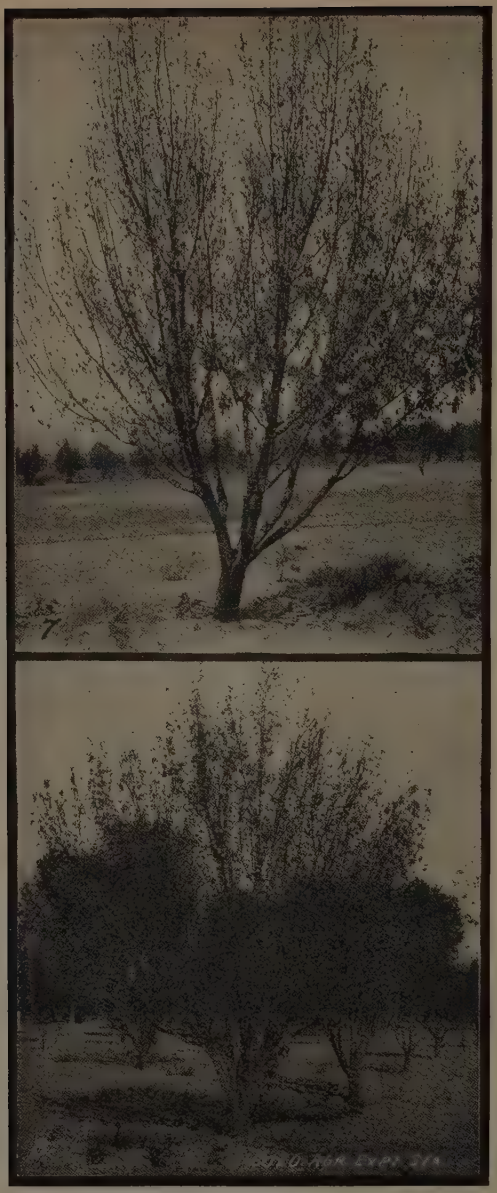
	Per Cent Nitric Nitrogen	
	In the row	Between rows
Near a fallow spot	0.000075	0.000100
In the fallow spot		0.002800
In the row nex to the fallow spot	0.000400	.....
First full row on north side near west end	0.000150	0.000050
Nineteenth row from N. side near W. end	0.000150	0.000200
Thirty-fifth row from N. side near W. end	0.000300	0.000075
First row on north side near east end	0.000500	0.000100
Forty-seventh row from N. side near E. end	0.000300	0.000150
Midway between ditch and fallow spot	0.000500	0.000150
Fifth row south of fallow strip	0.000200	0.000500
One hundred feet from S. and E. sides	0.000200	0.000100
One hundred feet from west side between ditch and fallow spot	0.000200	0.000300
One hundred feet from W. and S. sides	0.000250	0.000250
The middle of the field	0.000200	0.000075
Twenty feet south and east of fallow spot	0.000100	0.000075
Near the fallow spot	0.000150	0.000100

These samples were taken between the beets in the rows and between the rows to see whether any difference in the percentage of nitric nitrogen could be detected.

SAMPLES TAKEN TO A DEPTH OF 2½ FEET.

October 18, 1909.

	Per Cent of Nitric Nitrogen
South of Agr'l Hall near N. end of grain field	0.000070
South of Agr'l Hall near the S end of grain field	0.000350
South of Agr'l Hall near the W. side, alfalfa 1908	0.000100
Unused roadway next to the beet plot	0.001600
Between plants, alfalfa plot Expt. Farm	0.000800
In the beet plot, among the beets	0.000075



Plates VII and VIII. See Page 43.

SAMPLES TAKEN OCTOBER 18, 1909.

	Per Cent Nitric Nitrogen		
	Top 2 in.	From 2 in. to 6 in.	From 6 in. to 12 in.
outh of Agr'l Hall near N. end	0.000350	0.000300	0.000200
outh of Agr'l Hall near S. end	0.000250	0.000250	0.000500
outh of Agr'l Hall near W. side	0.000300	0.000070	0.000100
. Agr'l Hall 50 ft. from Col. Ave. E. side.	0.000800	0.000800	0.000800
outh of Agr'l Hall, middle of field	0.000500	0.000150	0.000250
outh of Agr'l Hall S. W. portion of field	trace	none	trace
Alfalfa plot, Expt. Farm	0.002000	0.000700	0.001000
lfalfa plots Expt. Farm between plots	0.001000	0.000600	0.000800
lfalfa plots, Expt. Farm between healthy plants	0.001000	0.000200	0.000300
lfalfa plots, Expt. Farm stand poor	0.000600	0.000600	0.000600
ornfield S. of alfalfa plot	0.000800	0.000250	0.000100
nused roadway next to beet plot	0.001000	0.001000	0.001800
eet plot, among the beets, between ditch and fallow spot	0.000400	0.000075	0.000050
eet plot, fallow strip 150 ft. from W side.	0.000800	0.000400	0.000400
eet plot, middle of patch among beets	0.000050	0.000025	0.000025
eet plot, S. W. corner among beets	0.000175	0.000100	0.000100
eet field, fallow spot	0.000400	0.000300	0.000200
eet field, southeast portion among beets.	0.000250	0.000025	0.000025
eet field, fallow strip near east end	0.003500	0.001200	0.000800
eet field, among beets near east end	0.000150	0.000025	0.000025
eet field, among beets N. W. corner	0.000300	trace	0.000050
eet field, among beets middle N. side	0.000100	trace	0.000050
eet field, among beets W. side	0.000100	0.000025	0.000050
rain field, south of beet field	0.000500	0.000450	0.000250
at field, north of beet field	0.000100	0.000025	0.000050
irgin soil Sec. 4, T. 6, R. 59 W., top 6 in		0.000800	.....
irgin soil Sec. 34, T 6, R 59 W., top 6 in		0.000800	.....
irgin soil, Yuma County, Colo		0.000120	.....
oil Lab. No. 869, Rocky Ford, Oct. 11, 1909		0.006400	.....

According to these results we find rather large amounts of itric nitrogen in our surface soils. For instance the unused road ay at the edge of the beet field gave in the top two inches on ctober 4, 0.005 per cent nitric nitrogen. This is equivalent to 03 per cent of sodic nitrate, 200 pounds per acre in the surface vo inches of this soil. The roadway is really only a driveway etween two plots of ground and has not been used, so that there as scarcely any more probability of the results having been influ- nced by the voidings of animals than any spot in the beet plot self. The sample taken two days later gave nitric nitrogen equi- alent to 0.020 per cent of sodic nitrate. This would give 140 ounds in the surface two inches. I am using 6 as the factor for con- erting nitrogen into sodic nitrate. The more exact factor is 6.0534. n October 16, we obtained much less, 40 pounds in the same epth of soil per acre. The alfalfa plot mentioned in these notes a young nursery, the plants are small and set, I think 3x3 feet.

*This is a young nursery; the plants are very small and occupy only small portion of the ground.

It is almost fallow ground. The beet field was a cropped field with the beets well grown and the ground well shaded. Here we find an average of 0.0000975 per cent of nitric nitrogen not including the fallow strip for the depth of from 2 to 6 inches. This is equivalent to 7.8 pounds of sodic nitrate in these four inches of soil per acre. These examples include our extremes but these are small quantities compared with the nitrate content of the first foot of soil of Orchard No. 2, 49.5 tons, or with the soil from the 5th to the 17th inch inclusive from Orchard No. 1, 6.5 tons per acre foot. While the nitric nitrogen in the soil of the College farm is probably normally high, it is simply not comparable to the samples of soils from these orchards. The Rothamsted experiments showed that during a period of from 14 to 15 months nitric acid equivalent to 553 and 572 pounds of commercial sodic nitrate was formed in the first 27 inches of soil per acre. This included the amount removed by drainage. This would give us 0.00625 per cent sodic nitrate counting the weight of an acre foot of soil as 4,000,000 or 0.00726 per cent counting it as 3,500,000 pounds.

The general character of these soils is given by the following analyses.

ANALYSES XXX, XXXI, XXXII AND XXXIII.

	No. 724 per cent.	No. 725 per cent.	No. 697 per cent.	No. 785 per cent
Insoluble	54.653	57.068	76.500	64.820
Silicic Acid	19.805	12.754		5.650
Sulfuric Acid	0.047	0.049	0.320	0.810
Chlorin	0.032	0.059	3.090	0.890
Phosphoric Acid	0.120	0.127	0.120	0.180
Carbonic Acid	3.048	6.312	3.470	7.040
Lime	6.100	8.465	3.490	7.180
Magnesia	1.355	1.448	2.080	2.190
Sodic Oxid	0.290	0.432	0.840	0.840
Potassic Oxid	0.872	0.742	0.590	0.690
Ferric Oxid	5.601	3.499	3.040	3.110
Aluminic Oxid	3.738	5.397	4.020	2.250
Manganic Oxid (br)	0.118	0.026	.....	.....
Moisture	.....	.....	1.370	1.470
Ignition	5.072	3.887	1.760	2.970
Sum	100.851	100.265	100.690	100.090
O equiv. to Chlorin	0.007	0.013	0.690	0.200
	100.844	100.252	100.000	99.890
Total Nitrogen	0.147	0.069	0.080	0.072
Humus	0.426	.....	.....	0.248

Samples 724 and 725 represent the soil and subsoil of the Experiment Station plots. The surface soil has a depth of one foot and the subsoil was taken to a like depth, so the samples represent the first two feet of the plot. Samples 697 and 785 represent soils of orchards which have suffered severely from the effects of excessive quantities of nitre. These four soils differ principally in the

amount of silicic acid set free upon digestion with hydrochloric acid. The carbonic acid may be considered as existing wholly as calcic carbonate which is essentially correct, for the calcic carbonate can be detected in most of the soils by simple physical examination. The humus in our soils is usually low in percentage and though apt to be richer in nitrogen than the humus of states with a higher rainfall it is not always so. The total nitrogen content of our soils as indicated by a fairly large number of analyses is not far from 0.10 per cent. It follows that a great many of them are below this amount. The four samples given illustrate this and show that there is no excessively large quantities of nitrogen present in the soil. The nitrogen determinations were made by the plain Kjeldahl, as it was not supposed that the nitrates were present in sufficient quantities to influence the results, assuming that this is correct it would appear that about one half the nitrogen in number 697 was present in the form of nitrates for we found 0.037 per cent of nitrogen calculated on the air dried soil in the aqueous extract as nitrates. The amount of nitrates present in the soil at a given time seems never to have been made the subject of study, probably because they are very small. The Rothamsted experiments lead to the conclusion that in good agricultural land cultivated as bare fallow about 80 pounds of nitrogen were transformed into nitrates in 14 or 15 months between the removal of the preceding crop and the taking of the samples. This includes the nitrates carried out of the land by drainage. The source of these nitrates is not considered. They may have been and probably were largely formed partly by nitrifying processes, partly by fixation. Storer further states "In three fields at Rothamsted 56.5, 58.8 and 59.9 pounds of nitrogen in the form of nitrates were found in September and October taking the soil to a depth of 27 inches. In one of these fields 49 pounds of nitric nitrogen occurred in the uppermost 18 inches. This result was due to the richness of the soil in nitrifiable matter. The other two fields in less favorable agricultural conditions contained only 33.7 and 36.3 pounds of nitrate nitrogen in the uppermost 18 inches of soil." Lipman states that "The determinations of nitrates, at Rothamsted, in the drainage waters of land that had been kept fallow, showed an annual removal of 40.2 pounds of nitrate nitrogen per acre." The maximum of nitric nitrogen here given, 59.9 pounds, gives only 359.4 pounds of nitrate of soda per acre taken to the depth of 27 inches; while we found in number 697, 9,040 pounds in an acre foot after the rich surface portion had been removed. This surface portion contained in the uppermost four inches of soil 22,747 pounds of sodic nitrate. It is understood that sodic nitrate is used simply as a convenient form of expression and is not intended as a definite statement that there were no magnesic or calcic

nitrates present. The fact is that in some samples we have had to combine the nitric acid with these bases because there were no other acids with which to combine them. Another consideration will give an idea of the amount of nitrates in our samples, especially of the surface samples, i. e., that the India saltpetre earth carries a total of nitrates varying from 1.6 to 12 per cent and that the caliche worked in Chile carries from 21 to 51 per cent while these samples carry from about two tenths to more than six per cent of the air dried soils.

It may be thought that the amounts of nitric nitrogen given for our good agricultural soils are exceptional, even for Colorado, in order to answer any such misgiving which some may entertain, I append tables containing 100 determinations representing 64 different fields.

The following 46 samples represent as many different beet patches. The samples were taken to a depth of six inches, October 1-15, 1909.

NITRIC NITROGEN IN FORTY-SIX SAMPLES OF BEET SOILS.

Results Given in Per Cent of Air-Dried Soil.

1.	0.001250	24.	0.000200
2.	0.000050	25.	0.000075
3.	0.006000	26.	0.000100
4.	0.008000	27.	Trace
5.	0.000120	28.	0.000050
6.	0.002000	29.	0.000025
7.	0.000075	30.	0.000800
8.	0.000800	31.	0.000025
9.	0.003500	32.	0.010000
10.	0.000050	33.	0.007000
11.	0.000800	34.	Trace
12.	0.004000	35.	0.000050
13.	0.000600	36.	Trace
14.	0.000600	37.	0.000100
15.	0.000100	38.	0.002500
16.	0.002000	39.	0.000150
17.	0.000075	40.	0.001250
18.	0.000100	41.	0.004000
19.	0.000200	42.	Trace
20.	0.000200	43.	0.001500
21.	0.012000	44.	0.016000
22.	0.003500	45.	0.001500
23.	0.000800	46.	0.000075

The above samples represent a variety of soils on which beets are grown. Some of the land is low and heavy, some of it high, light and well drained. The table shows that the amount of nitrates represented in these soils varies from a trace to 1,920 pounds in the top six inches of soil.

The following 54 samples from 18 different beet fields collected Jan. 26-31, 1910, show the amount of nitric nitrogen in the top six inches of the soil at this date.

NITRIC NITROGEN IN EIGHTEEN BEET FIELDS.

Results Given in Per Cent of Air-Dried Soil.

Number	In the Beet Row	In the Furrow	In the Turning Row
1.	0.000625	0.001375	0.000625
2.	0.001	0.0015	0.003
3.	0.000375	0.0002	0.000375
4.	0.0015	0.003	0.008
5.	0.0002	0.000375	0.0015
6.	0.001125	0.0005	0.00175
7.	0.0004	0.0001	0.0005
8.	0.0005	0.001	0.002
9.	0.000125	0.0005	0.00025
10.	0.005	0.000875	0.0005
11.	0.00075	0.000625	0.0005
12.	0.0001	0.0002	0.000375
13.	0.00025	0.00075	0.000375
14.	0.0015	0.00075	0.0005
15.	0.000875	0.0005	0.014
16.	0.00006	0.00008	0.0002
17.	0.000875	0.00125	0.001
18.	0.001	0.00075	0.001

The preceding table gives us an idea of the amount of nitric nitrogen in our cultivated soils. All of the samples were tkaen to a depth of six inches. The activity of the azotobacter is assumed to have been moderate not only at the time the samples were collected but also for a rather long period before, as the ground had been frozen at least two months prior to this date, and had remained frozen for some time. The rains and snows during the autumn had tended to wash the nitrates deeper into the soil. The amount of rain fall during the months preceding the taking of these samples or practically from September 1st to February 1st, was 3.83 inches of which 3.36 inches fell between September 12th and December 1st.

The samples were taken, as we see, in mid-winter from fields which had been in beets and after a season with heavy rain or snow falls in late autumn and severe freezing. The crops would naturally be supposed to remove considerable quantities of nitrates, the rains and snows would be expected to wash them into the deeper portions of the soil, and the freezing weather should have retarded the activity of the azotobacter. Still the table reveals the presence of nitric acid equivalent to 180 pounds of sodic nitrate in the surface six inches of two of these fields and 600 pounds in another. These samples were taken between beets in the rows. The samples taken in the furrow between the rows give us a maximum corresponding to 360 pounds of sodic nitrate in the top six inches of soil. The turning row, however, gives us an idea of the amount of nitric acid that may be present and at the same time some idea of the difference in the amount of nitric acid or its corresponding nitrate due to the presence of beets. We have for the fourth farm nitric acid between the beets corresponding to 180 pounds of sodic

nitrate, Chile saltpetre, in the upper six inches of the soil, and in the soil of the turning row there is five times as much, 900 pounds. We sometimes find less nitric acid in the middle between the rows than between the beets in the rows, though we usually find more. The presence of larger quantities of nitric acid in the fallow ground of the turning row is a fact which one would expect as the sunshine, air and soil conditions are favorable for its production. The same is true for even small spots within the beet field which for some reason or other may chance to be fallow. The percentages of nitric nitrogen found in the beet plots at this station may be used to show this; in a fallow, i. e., a bare spot 0.002800 per cent; between the beets in the row next to it 0.00040 per cent. Again in the beet field among the beets 0.0001; in an oat field 0.0001; in a fallow strip 0.0035; in another fallow spot in the field, 0.0004 per cent.

The significance of the analytical data may be presented by the following averages representing the College farm at Fort Collins:

	Per Cent of Nitric Nitrogen
71 Samples 2 and 3 inches deep, Oct. 4-18, 1909	0.000626
28 Samples 3 to 6 inches inclusive, Oct. 18, 1909	0.000515
25 Samples 7 to 12 inches inclusive, Oct. 18, 1909	0.000329
6 Samples 2 1-2 feet deep, Oct. 18, 1909	0.000499

The following samples represent other farms, sixty-four in number:

	Per Cent of Nitric Nitrogen
46 Samples 6 inches deep, Oct. 1-15, 1909	0.002005
54 Samples 6 inches deep, Jan. 26-31, 1910	0.001271

The College land contained in October less than one-third as much nitric nitrogen as the other 46 farms sampled at the same time, and about one-half as much as 18 other farms sampled in January, 1910. This is very striking as the samples from the College farm were taken to a maximum depth of three inches while the others were all taken to a depth of six inches.

That there has been a decided deterioration in the quality of our beets within the past six years cannot ,I think, be doubted. Many causes may have attributed to this, but the discussion of these at this time would be out of place. Suffice it, for the present purpose, to state, that there are many fields of good beets every year, but that in spite of this the average quality has been deteriorating. The past few seasons seem to have been especially favorable for the production of nitrates in the soil, and I am of the opinion that there is a direct and intimate relation between these facts.

The amount of nitric acid present in the sugar beet is usually assumed to be small, more in the French beet than in the German, but the amount is always small. Further the nitrates are usually considered as molasses formers. We have examined our beets

qualitatively for nitric acid and find it present in quantities, which are easily detected. I have been kindly furnished with samples of Steffens waste water from several factories in this state and find them uniformly rich enough in nitrates to give a strong reaction without one's going to any particular trouble to prepare the waste water. There is nothing new in the occurrence of nitric acid or nitrates in beets. It has been shown that the leaves have contained as much as 0.16 per cent of their green weight, which is stated to be exceptional in plants. Stock beets have been found to contain 0.126 per cent and sugar beets 0.164 per cent of their green weight. The last percentage was found in beets which had been heavily manured with saltpetre or other highly nitrogenous manures. No information is given concerning their deportment in the factory. The nitrates have been considered as exercising a prejudicial influence on the working qualities of the beets if applied alone, in considerable quantities and after the plant has attained to some size. It seems possible that we may have in these facts the explanation for the deterioration of our beets. The nitrates are being continuously formed in our soils. In the turn row of field fifteen, we find nitric acid equivalent to 1,680 pounds of sodic nitrate in the surface six inches per acre whereas we find the equivalent of only 120 pounds in the furrow between the rows. We must be careful about drawing extreme conclusions in regard to the amount of nitrates used by the crop. The quantity was almost certainly materially less than the difference between 1,680 and 120 pounds because the ground had been shaded by the beets during most of the season and this would make some difference; further, the row had been washed out by the irrigation water applied, etc., but the possible supply for the beets grown on this field was as much as 1,680 pounds in the top six inches of soil per acre. This determination was repeated and checked by the determination of the nitric acid in the aqueous extract of the soil by a different method.

The soils here considered are such as were planted to beets last season, 1909. The extreme cases given in other portions of this bulletin are soils in which this process of fixation has proceeded so far that they are now barren, due to the excessive amounts of nitrates.

The past season may have been an exceptionally favorable one for the azotobacter and we may not have the recurrence of such serious results for years; there is, however, no assurance that this may be the case. In fact we have no data relative to the effects of the season upon the activity of the bacteria.

One question has undoubtedly suggested itself in regard to the origin of these nitrates, i. e., whether the popular idea that the irrigation water brings them to the surface may not be correct. Some

at least will deem this question as deserving a definite answer especially as I have found that the waters issuing from the shales underlying the mesas carry significant quantities of nitrates. The shales themselves when a sufficient quantity of them, 1,280 grams, were extracted with water actually showed the presence of a trace of nitric acid. There are two samples of waters and one of shale. They represent three different localities, two of them within three miles of one another while the third is more than 50 miles from either of the other two. This might mean that the shale area is very large and though it contains but a trace of nitric acid it might suffice to furnish all of the nitric acid which has been found, especially as this water has been issuing from these shales and filling up the lower portions of the country for a very long period. This can all be answered very easily by stating the following facts. The mesas above these shales are cultivated and bad nitre spots occur on top of them, in one case 80 feet above the level at which the water was taken. Second, that nitre spots occur in entirely different geological formations where these shales do not occur, in alluvial deposits and under our ordinary prairie conditions, in other words the shales considered as a source of the nitre would not be adequate for the explanation of the greater number of occurrences and independent of any other reason than their insufficiency, we must seek for a more general source or a cause sufficient to account for all of the occurrences assuming that they have a common cause, which is reasonable, at least, until we are sure that they have different causes.

The occurrence of nitrates in the waters and apparently in the shale is susceptible of an easy explanation, i. e., the nitre spots which are only exaggerated instances of a general condition, occur in the lands above the shales. The water that falls or is put upon these lands washes the nitrates down into the shales. The soil has no power to retain these salts and this seepage water is simply washing the nitrates out of the land. The shale from the brick yard was saturated with this water and the same water was used in making the brick. A trace should be present in the aqueous extract of the shale as we find was the fact.

The effect of the nitre on vegetation has been alluded to; the spots where the soil is rich in nitrates is entirely barren. See Plate II. The most serious manifestation with which we have yet met was the rather sudden death of a large number of apple trees mostly in June 1909. See Plate III. Plate IV is a view of the same rows outside of the affected area. The leaves began turning brown at the apices, then along the margins until the whole leaf was involved. See Plate I. Sometimes it did not affect the whole tree, only a few limbs being attacked. Other trees, beside apple trees

were attacked. A number of cottonwoods were affected in this way. As elsewhere stated the condition of the soil in regard to excessive water was immediately investigated but we could not find any reason for attributing the trouble to this cause. One case in particular was instructive, it was in the remnant of the orchard designated Orchard No. 2. See Plates II, VI and VII. Plate VII gives a good idea of the size of this barren area as well as the killing of the remaining trees. The trees in the background are of the same age as those in the foreground. The dead tree in the middle of the background is the same tree that appears in the foreground of Plate II.

There are a few trees on the east side of the orchard which had up to that time remained in very good condition, in fact, were quite thrifty trees. These trees are shown in the background of Plate VI. These trees died suddenly. Plate VIII shows a tree killed late in the summer. The crowns and roots of these trees were apparently healthy. The roots were followed for six or eight feet from the trunk of the tree, nothing could be found to indicate any cause for the deportment of the tree. I had known for three years that this ground was very rich in nitrates and locally in chlorids. This determined me to make some experiments with nitre and salt. The nitre in this soil amounts to many tons per acre foot, 56.7 tons in the surface foot. It was evident that I had to deal with large quantities so I applied nitre to some young trees in an experimental orchard and irrigated them to bring the nitre solution in contact with the feeding roots. The amounts applied were from 5 to 20 pounds per tree. The results were that in those trees, about which I buried five pounds of nitre each, some of the limbs were reached and others were not, in other words in applying the nitre, (Chile saltpetre was used in this experiment), I had reached some of the feeding roots but the others had escaped. With the application of 20 pounds I succeeded in reaching all of the roots, at least I killed the tree in about four days. Judging from the deportment of these trees, I can conceive of ones failing in an experiment of this sort, even though he applied large quantities of nitre or other poison provided the poison was not put within the feeding area of the roots for the effects produced on different trees was by no means proportional to the amounts applied to the soil, the application of five pounds produced just as pronounced results as the application of 10 pounds. This of course depended upon the root system of the tree and the location of the nitre. The effects were in all respects similar to those produced in the other orchards, the beginning and progress of the effects, the killing of the leaves, the deportment of the tree in throwing out a few whitish-yellow leaves and the appearance of the bark and wood after death, were identical. An

application of large quantities of salt proved injurious but did n produce these effects. Prof. C. S. Crandall of the University Illinois, also experimented on the effects of nitre but he introduc the solution under the bark by properly attaching a vessel fill with a solution of nitre to the tree. He wrote me that the resu was the same as on the trees which I had shown him. There no doubt but that the nitre in the soil is capable of producing the effects. The more observant and intelligent orchardists also blan the "black alkali" which in this case is nitre, it may be calcic, ma nesic, or sodic nitrate and is probably usually a mixture of t three. A very simple explanation for the death of the trees sugges itself. The nitrates accumulated in the surface soil were probab carried down to the roots by a rain fall or an irrigation at a tin when they were very active and enough of the nitre was gather to do the injury. I am convinced that this simple explanation the correct one. It matters not that there is arsenic in this so These trees are not affected in the least as those are which are i jured by arsenic. These may grow thriftily until the time of the being killed. This trouble is not scattered through hundreds orchards or even through one orchard, a tree here and there, b is confined to areas. See Plates II, IV and V. The orchar designated as Nos. 2 and 3 have been totally destroyed in part these parts of the orchards constituting an irregular but continuo area. Other orchards present similar conditions. Both old ar young trees have been killed during the past season, nineteen hu dred and nine.

This is the only effect of this soil condition that I wish present at this time though there are other serious agricultur conditions which I believe we will find attributable to this caus i. e., to an excess of nitre in the soil. Sometimes too much at o time as is attested by the death of apple and also other kinds trees, sometimes to too great an aggregate supply during the seaso The following may illustrate what I mean by the latter statemen It is generally conceded that the application of nitrates to the sug beet except in the earlier stages of its growth is detrimental to t quality of the beet. The following recommendation has been ma in regard to the application of nitrates to this crop. One hundr and seventy pounds per acre applied in conjunction with farmya manure in the fall and 245 pounds also with manure in t spring, a total of 415 pounds. This is applied either on the surfa or near it and the crop is not supposed to receive further applic tion of nitrates during the season. But what will be the conditio of the crop if it should receive a continuous supply amounting du ing the season to, say, 600 or 800 pounds or is planted in soil whi already contains several times this amount per acre. If the assum

ion that nitrates injuriously affect the quality of the beet when present in large quantities, then beets grown in such soils ought to e very poor, not necessarily in crop but in quality. I have seen eets planted in ground so rich in nitrates that when the water oluble residue, amounting to 4.6 per cent of the air dried soil, was reated with ferrous sulfate and sulfuric acid the red brown vapors f NO_2 could be seen filling and even flowing out of the test tube. This sample of soil was taken October 11, 1909. There was only ere and there a straggling beet in this portion of the field. Adoining this was an area of big green tops with medium sized, hite, brittle beets. The sugar content and coefficient of purity ere not determined. This study has probably only been begun.

Plate V illustrates a beet field, not the one referred to above. he amount of nitric acid in this soil is very high, as high as that f some of our orchard soils in which it is measured by the ton per cre foot of soil. I have tried to give facts enough to place the ccurrence of these very large quantities of nitrates in our soils eyond question. I have endeavored to give reasons for believing hat the nitrates are not derived from the shales which are often opularly assumed to be the source of this "black alkali" or nitre. have given one instance of its serious effect upon orchard trees ut hold back other features of its influence upon our agriculture or further study.

Unaided by bacteriological investigation, until within the past ear, I had to content myself with a theory in regard to the source f these nitrates. I found a few things common to these occurences. They were all so situated that while the water was not excessive there was an adequate and constant supply of it. The soils re almost uniformly comparatively poor in nitrogenous matter and here is always an abundance of carbonate of lime. We have some ccurrences of these nitrates in the northern parts of the state but hey are always in places where we have comparatively even, high emperatures for goodly periods at a time. These are favorable conditions for the development of a bacterial flora. I believed that in hese places the flora was a nitrogen fixing one. I presented these iews to Professor Sackett and have been fortunate enough to btain his aid in carrying the investigation further on bacteriological lines. Considerable preliminary work has already been done nd we purpose to continue the work in the field and in the laboraories even beyond the limits which we now see and there is much ork within these limits. Professor Sackett and I have already athered samples from several sections of the state. All of the amples so far examined are from localities that I have known for everal years and in one sense are from promising places, i. e., from ections rich in nitrates. Some of the samples are unfortunately so

rich in nitrates that the nitrogen fixing flora has practically pe ished. One thing is characteristic of them all, i. e., the brown colo of the soil, hence the common term "black alkali." This is mos striking along the roadsides where we sometimes can observe th dark color continuous for as much as a mile at a time. No sample were taken from such places. The dark color is possibly due t the bacterial flora itself as the azotobacter form yellow brown c dark brown films. The following numbers are simply laborator numbers for a preliminary series and may not again be presented this of course is entirely in Professor Sackett's hands. Professo Sackett found that these samples were comparatively rich in nitro gen fixing bacteria of which he finds a considerable variety. It i not time to state any conclusion even tentatively held. Professo Sackett has given me the following results which may suffice fo the present purpose, i. e., to place the source of these nitrates be yond a reasonable doubt. The nine samples represent five localities

Number 1.—A surface soil very rich in nitrates.
Number 2.—This sample is from the same locality taken to a depth o 6 inches.
Number 3.—Same locality 12-14 inches deep.
Number 4.—Taken as normal soil for this locality, 2-6 inches deep, n water at a depth of five feet.
Number 5.—Another locality from 2-6 inches deep.
Number 6.—Another from 2-6 inches deep.
Number 7.—Another locality from 2-6 inches deep.
Number 8.—Normal soil near No. 7.
Number 9.—A normal mesa soil in an alfalfa field with no apparen trouble.

NITROGEN FIXATION.

Milligrams Nitrogen Fixed in 100 CC. Mannite Solution, Infusion of 1 Grams of Soil Added.

	10 Days	20 Days	30 Day
Number 1	0.00000	0.00000	1.0507
Number 2	0 00000	1.19085	0.5604
Number 3	1.78627	3.08220	3.4324
Number 4	3 92780	6.16440	12.4689
Number 5	0.63045	0.84060	3.0822
Number 6	0.07213	0.77055	3.5726
Number 7	1.72130	3.50250	3.0121
Number 8	1.87562	2.38170	2.8720
Number 9	4.13431	13.02930	10.1572

All questions of technique and further detail will be presented by Professor Sackett in due time.

The great variety of soils in which I have observed this trouble and the variety of differences in the appearances of these places make one hopeful of very interesting results.

We may be pardoned for adding the following consideration possibly of some geological interest. The source of the nitrogen present in the Chile saltpetre beds has been the cause of much speculation. The source of the nitrogen in the India saltpetre earth is considered as evident and the formation of the nitrates is sufficiently accounted for by the action of nitrifying bacteria, which

convert the nitrogen of the liquid excreta of the households into nitric acid which may be recovered in the form of potassic nitrate.

In the case of the Chile saltpetre we have no definite evidence regarding the source of the nitrogen and as a result we have a variety of theories to account for its presence in such extremely large quantities in the form of nitrates. Almost every conceivable source, the droppings of great herds of animals, guano or the droppings of birds, marine vegetation, etc., have been suggested. These sources attribute the formation of the nitrates to the action of nitrifying bacteria on nitrogen of animal or vegetable origin. I know that this has not always been stated in just this way. Another source which has been suggested is the atmosphere. It has been claimed that the hydrated oxid of iron has the power to induce the oxidation of ammonia salts and that other basic compounds, the alkaline carbonates, for instance, have the power under certain conditions of inducing the oxidation of atmospheric nitrogen. Again the electric discharge has been suggested as the cause of the union of the oxygen and nitrogen of the atmosphere to form nitric acid, which falling to the earth as a dilute solution of ammonic nitrate in rain water may have reacted with the carbonates of the alkalis or alkaline earths which would then be carried with the waters to natural basins from which the waters have subsequently evaporated leaving the nitrates in their present form and place.

The facts which I have found obtaining in such large districts in Colorado suggest the possibility that the atmosphere is the source of the nitrogen in these nitrates but that the agency which has transferred it from the atmosphere to the fixed form of the nitrates is not the electric discharge nor the action of alkaline carbonates on the nitrogen of the air in the presence of oxidizable matter, but to that of those micro-organisms, the azotobacter, which have the power of converting atmospheric nitrogen into nitric acid, respectively into nitrates, especially if there be enough calcic or other carbonate present to prevent the soil from becoming acid.

We have in miniature a great many analogies to the occurrences of Chile. In the lower parts of small basins we have deposits of sulfate of soda, above this zone we have one rich in nitrates. I have been told that in Chile they sometimes find calcic chlorid but usually sodic chlorid. We find samples in which calcic and magnesic chlorid together constitute 48.5 per cent of the water soluble portion. Others in which sodic chlorid constitutes 44.5 per cent of the water soluble. The amount of nitrates, dealt with in this bulletin, is surprisingly large. We have as the highest percentages of nitrates found, 5.628 and 6.541 per cent of the air dried samples. These samples were gathered from the surface soil and were not taken to any depth, perhaps the one showing 5.628 per cent

may have reached a depth of two inches, but the area involved was small. The other sample may have reached a depth of an inch but the area involved was large, some eight or ten acres. In the case of another sample taken to the depth of five inches we find the nitrates equal to 2.571 per cent of the air dried soil. This sample was taken to a medium depth and the area involved is at least eight acres and we would have 344,000 pounds or 172 tons of sodic nitrate in the top five inches of this land. In another sample taken to a depth of four inches we find that 1.706 per cent of the air dried sample is sodic nitrate. The area involved represented by this sample is certainly as large, i. e., eight acres, and we would have 189,971 pounds or practically 95 tons in the top four inches of this land. The largest amount of nitrates indicated by the analysis of any sample taken to a depth greater than four inches was in the case of a sample taken to the depth of one foot which contained 2.837 per cent of sodic nitrate corresponding to 113,480 pounds or 56.74 tons per acre in the surface foot. These figures are given to show the large aggregate amount of nitrogen which is being taken from the air and converted into nitrates in these semi-arid soils usually fairly rich in sulfate of soda and containing large amounts of calcic carbonate.

The aggregate area involved in this active fixation of nitrogen would be difficult to estimate accurately but as stated elsewhere in this bulletin it is present in widely separated sections of the state. In some places only a small area may be involved, in others it is almost continuous for miles.

SUMMARY.

The cause of the barren spots in some sections of Colorado which is popularly, though incorrectly, called "black alkali" is the presence of excessive quantities of nitrates.

These nitrates do not come from the soil nor from the shale as frequently assumed but are formed in the soil.

The death of many apple trees, some poplars and other shade trees during the season of 1909 was caused by excessive amounts of nitrates in the soil.

These nitrates were carried down within the feeding area of the roots by the spring rains and irrigation.

The amount of these nitrates accumulated in some of these soils is already very large, amounting to many tons per acre foot of soil, 100 tons per acre foot having been indicated by some samples.

The agency by which the nitrogen of the air is converted into these nitrates in the soil is a group of micro-organisms possessing the power of converting the nitrogen of the air into nitric acid.

These organisms have a very wide distribution in our soils and are not always hurtful, but when the conditions of the soil, including moisture, temperature, and the presence of much alkaline earth carbonate, become very favorable they develop so vigorously that they produce the effects recorded in this bulletin.

These organisms thrive in some of our best cultivated lands, and some of the anomalies of our agriculture are probably due to them.

The very considerable amounts of nitrates found in some of our soils, together with the large areas so enriched, and their wide distribution suggest the probability that the formation of the nitrates of Chile and Peru may have been due to the agency of these organisms.

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BUTTER MAKING

CLEAN MILK AND COMMERCIAL STARTERS

(Information Bulletin).

BY

WALTER G. SACKETT

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CLEAN MILK AND COMMERCIAL STARTERS AS FACTORS IN BUTTER MAKING

By Walter G. Sackett.

It is a fact familiar to all of us, whether we are buying butter or whether we have butter to sell, that farm, ranch and country butter seldom, if ever, commands as high a price on the retail market as creamery butter. There are no doubt cases where precedent, alone, dictates the price of the farmer's product, it having become an established custom in certain towns and at certain stores to pay the countryman from five to ten cents per pound less for his product than for the creamery goods. Injustice is often done the farmer in this way, for some country butter is equal in quality, if not superior, to creamery butter. Why, then, this universal custom of rating the creamery product above that of the ranch? The cold truth of the matter is that the average run of ranch butter is inferior in flavor and keeping qualities to the ordinary creamery output, and the consumer is not willing to pay the factory price for the inferior home article. The question at once arises, why this should be the case, for, most certainly the conditions which enter into good butter making ought to be more easily controlled by the individual farmer, who can give his personal attention to each step in the process, from the milking up to delivery to the consumer, than by the creamery overseer who must take the whole milk or gathered cream from many different sources, some clean, some filthy, and mix it all together. Yet by proper handling from this point, he is able to turn out a first class product. Of course, it goes without saying that no one can make as good butter from dirty, filthy cream as from that which has been produced on a clean farm where some attention is given to the sanitary conditions. Cleanliness is without question the first and foremost consideration in making either good butter or cheese. The word *cleanliness* when used in connection with the dairy and dairy products has a very broad meaning and demands the attention of everyone who has anything at all, no matter how insignificant, to do with the care and handling of the milk and cream. The farmer who does the milking is apt to forget that dirt and filth are intimately associated with his part of the work, and no matter how careless he has been with the milking, he expects the good housewife to turn out a butter of excellent quality, which will score as high or higher than the creamery product. This is absolutely impossible and out of the question.

Those who are engaged in butter making as a profession consider that the two most important factors in good butter making are clean milk and proper ripening of the cream. Both of these can be con-

trolled by the butter maker no matter whether the output is a thousand pounds a day or six pounds a week. Clean milk can be obtained only by the most scrupulous care on the part of those who are entrusted with the handling, and the proper ripening of the cream is best accomplished by the use of what are known as *commercial starters,* which will be discussed fully later on.

To the majority of people who use milk or cream in one form or another, *clean milk* signifies milk free from visible dirt, such as cow hair, hay, straw, etc. As a matter of fact, such forms of dirt are seldom met with in the milk as delivered to the consumer, and of themselves are practically harmless except to the esthetic taste. The milkman has learned to strain his milk and rid it of such debris. It is the filth that we can not see with the unaided eye that does the harm and makes the consumption of dirty milk dangerous. Every particle of dust, every hair, every bit of straw is covered with myriads of bacteria, and when these foreign substances find their way into the milk, the germs are washed off and immediately begin to grow and multiply in the milk. When we know that a single cow hair may harbor from 4,000 to 10,000 germs which can multiply once every half hour, are we not justified in labeling milk which contains such hairs as unfit for use?

When every precaution is taken against contamination, it is possible to obtain milk directly from the cow which contains as few as 200 to 300 germs per cubic centimeter (one-fourth of a teaspoonful); with somewhat less care the numbers will increase to 5,000; when carelessly drawn and handled, it frequently contains in the beginning from 25,000 to 100,000.

Many of our large cities have placed a limit to the number of bacteria which the city milk supply may contain and yet be offered for sale. The city of Boston (1) has set this number at 500,000, Rochester, N. Y., 100,000, and Milwaukee 250,000. In New York City, Park (2) found that during the coldest weather, the milk sold in the shops averaged over 300,000 bacteria per cubic centimeter; during cool weather, about 1,000,000 and during the hot weather, about 5,000,000. In Chicago, Jordan and Heineman (3) found in market milk collected during April, May and June, numbers ranging from 10,000 to 74,000,000. Sedgwick and Batchelder (4) have examined samples of milk from groceries in Boston which contained over 4,500,000. Stevens

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(1). Article 51, Sect. 1. Regulations for the Sale and Care of Milk, Boston Board of Health.

(2) Park: Jour. Hyg., 1, 1901, 1, p. 391.

(3) Jordon and Heinemann: Rept. of Civil Federation of Chicago, 1904.

(4) Sedgewick and Batchelder: Bost. Med. Jour., 1892, 126,p. 25.

(1) has shown the milk supply of Raleigh, N. C., to vary in bacterial content from 1,200 during November to 54,000,000 in May.

A number of the bacteria which fall into milk are harmless in themselves, but during their growth they bring about certain changes which produce disagreeable odors and flavors, and frequently deleterious substances. The natural souring of milk is accomplished by the lactic acid germ. However, Marshall (2) has shown that the lactic bacteria are favorably influenced by the presence of other bacteria, notably by germs of filth, which for the sake of the present illustration, let us call "B." The lactic germ we shall designate "A." By growing the lactic acid germ by itself and also by associating it with the germ B, Dr. Marshall has been able to show the increased number of lactic forms when associated with B in milk. At the time of loppering or curdling of culture A+B, the ratio of the lactic acid bacteria in the two cultures was:

A:A+B::27:1614.

Again, he has demonstrated that germ B produces stable products which withstand sterilization and exert the same influence over germ A in milk cultures as the living germ. The comparative number of lactic germs in culture A and in culture (A + products of germ B) was expressed by the ratio:

A:(A+products of germ B)::27:1007.

From this it follows that clean milk will keep sweet much longer than other milk. We see this same thing every day in a practical way when we notice that milk from certain dairies sours so much more quickly than that from other sources, and if we trace down this matter still further, we invariably find that the better milk comes from the cleaner stable.

There are also those forms of microscopic life which produce *bitter milk, ropy milk,* and milk of different colors commonly designated bloody milk, blue milk and yellow milk. If these bacteria are present in the milk, they will be present also in the cream and will impart their disagreeable properties to the butter made from it.

A few suggestions along the line of clean milk may not be out of place at this time. The writer feels that while this topic has been treated upon thoroughly and exhaustively in many publications and by institute speakers, yet, not all of us who are in the dairy business, have understood fully and put into practice the principles and methods advanced by the advocates of sanitary milk.

No dairyman who pretends to produce clean milk should allow his cows to have access to muddy bayous, wading places and irrigating ditches. It is not through any preference, but as a last resort, that cattle in the summer time stand knee deep in mud and water to get

(1) Market Milk, bacteriological data. Cant. of Bakt, II Abt. Bd. XX. No. 4-5. 1907, p. 114.

(2) Special bulletin No. 33, 1905. Mich. Exp. Station.

away from flies. If some other provisions were made for their comfort, they would not have to seek this refuge. Provide an abundance of shade in the pasture lot and fence off the mud.

See that there is an ample supply of good, clean, drinking water and wholesome food. It is much better to do all of the feeding and bedding after the milking is done, since in handling dry hay or fodder, the air is filled with dust and dirt which will settle into the milk at milking time. If the cows are allowed to eat while being milked, there is always more or less commotion caused by tossing the heads and nosing the feed, and this means a constant supply of dust in the stable. There may be some uneasiness shown at first if they are compelled to wait for their feed, but it is only a question of educating them to it. Those dairymen who are practicing this are getting good results and can testify to the improved quality of the milk.

Some of the cow stables which one sees in traveling through the country are a disgrace to any civilized community. Just because a cow *can* endure such accommodations is no excuse for their existence. Warm, well ventilated, well lighted stables will pay for themselves many times over in increased yield and quality of the milk. Fly screens are a very necessary adjunct to a good stable, and a frequent coat of whitewash will help considerably toward its appearance and sanitary condition. If the stable is properly constructed, the cows can be kept clean and comfortable, and their flanks free from great masses of manure, which, when dried, is apt to fall into the pail during milking. It is to this source that we can trace many of the objectionable "cowy" flavors found in the milk.

Manure must not be allowed to accumulate in the barn lot until the milker is compelled to wear hip boots to get through it on his way to the stable. The udder and flank of the animals should be wiped off with a cloth moistened with some germicide, such as 3 per cent. carbolic acid, or lysol, or 1-1000 mercuric chlorid, just previous to milking; the cows should be brushed frequently to remove any loose hairs or foreign matter.

Very few dairymen stop to consider the importance of cleanliness of their own person when working around milk. It is the usual practice to put on the filthiest pair of overalls available, since milking in the average cow barn is considered a dirty job, which in itself is, indeed, an admission of guilt. The same suit of overalls is used while milking, cleaning out the cow stable, bedding the horses and hauling manure, and it is not until they become so stiff and caked with filth as to make it difficult to get into them, that it is considered at all necessary to have them washed. The dairies of today, which are producing certified milk, furnish their milkers with a clean, white uniform every day. If we could do away with the long standing blue jeans and adopt a white suit we should realize very soon that the cow stables need cleaning up, and that the length of time required for a pair of overalls to become soiled is much shorter than was supposed formerly.

Milkers are not as particular about washing their hands before

milking as they should be. It frequently happens that the hired man will be called in from hauling manure or feeding the pigs, or some similar operation, to help with the milking. The chances are that he will never think of washing his hands, but, if, contrary to the usual custom, he should do so, nine times out of ten he will wipe them either on his dirty overalls or on a red bandanna that has escaped the wash tub some three weeks past.

It seems almost unnecessary to have to call attention to the danger of employing persons as milkers who are suffering with any contagious or infectious disease. Tuberculosis, typhoid fever, and diptheria may gain access to the milk through such channels, and epidemics follow as a result. No one who is afflicted with any of these troubles should be allowed any part, no matter how small, in the care and handling of the milk.

While speaking of the spread of disease through milk as the medium, the common house fly must be charged with being the most dangerous agent known to humanity in polluting milk, and the greatest menace to public health by way of spreading disease. The bare statement of this fact should be sufficient to convince any one of average intelligence of the great importance of exterminating this pest,

As a rule, the housewife, to whom is entrusted the cleaning of the pails, pans and cans, does her work more thoroughly than the others associated with her in the dairy work. However, it may not be out of place to mention one or two points in connction with her duties. The mere scalding of a utensil by pouring boiling water over it is not always adequate to sterilize it and render it sweet and clean. It is frequently necessary to allow water to boil in the pails and cans for a half hour or longer in order that the dirt and grease which find their way into the cracks and seams can be soaked up and gotten rid of. Some good washing powder should be used in this operation. The strainer cloths should be boiled thoroughly. After thorough rinsing with boiling water, the different utensils should be placed in the brightest sunshine available, and not on a bench on the shady side of the milk-house. Bright sunshine is one of the worst enemies of germ life, and since it is so effective and so cheap, let us use lots of it, not only in our milk cans, but in our damp, musty cellars, "spare" bed rooms, company parlors, and then turning toward the dark, gloomy barns, give the horses and cattle their share.

The writer has a farmer in mind whose usual custom is to cool off his milk bucket, which has been sterilizing in the bright sunshine for half a day previous to milking, by pumping water into it from a well located in the barn yard at the edge of a hog-wallow. This is certainly a very questionable procedure, since practically all of the good from scalding and sunning is counteracted and more than this there is often danger of introducing undesirable germs into the milk by this means.

It is a matter of common knowledge, that milk absorbs foreign odors very readily and retains them as tenaciously. It follows, natu-

rally, from this that milk must be kept in a clean, cool, well ventilated room, free from all taints and flavors. Anyone who has ever exposed a pan of milk in an ice box along with onions, boiled cabbage, cantaloupes or cucumbers, or who has placed it in a freshly painted or varnished room, or who has allowed the cans of milk to remain in a vile smelling stable for some time, knows the inevitable consequence. The cream from such milk must necessarily give its respective flavor to the butter made from it, and when the consumer complains of an off flavor, the ranchman proclaims his innocence.

Much of the dirt and dust, together with many disagreeable odors, can be obviated by arranging a small milk-room, adjacent to the cow stable and separated from the cows by a tight partitition. Here the straining can be done and the cans kept while they are being filled from the milkers' pails.

The cream should be cooled as soon after separation as possible in order to check the growth of bacteria. This can be accomplished easily by placing the cans, containing the milk or cream, in cold well water by which a temperature of at least 50 degrees F. should be obtained.

Inasmuch as the offensive germs thrive chiefly in the curdy part of the cream, it follows that a thick cream, low in curd, will keep better than a thin cream. For the same reason, poorly worked butter, conttining considerable buttermilk, will not keep as well as butter which is worked thoroughly. Consequently, it is best to separate as heavy a cream as the separator will handle and as is consistent with the time of year, say 35 per cent. in winter and 40 per cent. in summer. Besides obtaining a better grade of cream for butter making, the bulk is reduced, which simplifies the handling, and more skimmed milk is available for feeding purposes.

In closing this chapter upon the production of clean milk, its application to butter making must not be lost sight of. Stated briefly, it is simply this: high class butter can come only from clean cream and clean cream is possible only from clean milk.

The Use of Commercial Starters.

The natural flavor of well made butter from fresh, clean cream is very pleasing to the taste of the average person and it is chiefly this desirable flavor for which the consumer pays. It is obvious, then, that the goal toward which the butter maker must strive is a desirable flavor, accompanied by a pleasing aroma. To be sure, the texture can not be lost sight of, but when the layman buys a pound of butter, he judges it for flavor first of all, and inasmuch as his judgment will determine ultimately the demand for a certain brand of butter, it is important that his verdict be given the weight it deserves.

As noted above, the bacteria which are present in the cream, and which in the end find their way into the butter, are responsible in a large measure for the flavor. On the one hand, if filth germs dominate in the cream, then the butter will have a strong, rancid flavor and odor from the beginning. On the other hand, if the

cream has been gathered under sanitary conditions, with cleanliness in mind, all things being equal, a good quality of butter is to be expected. However, this last condition exists so rarely that it can be passed by with mere mention.

Now if it were possible to introduce into the fresh cream immense numbers of desirable bacteria which would give it a good flavor, and which would impart to the butter that "grassy" or "nutty" taste so much sought for, we might be able to control the flavor, in a measure, in spite of the unsanitary condition of the cream. The Starter fills this demand.

The Nature of a Starter.

Hastings (1) has defined a starter as "A quantity of milk in which acid forming bacteria have grown until the milk contains large numbers of them. The addition of the starter seeds the cream with great numbers of bacteria which are in a healthy condition and which, by their growth, cause the acid fermentation to progress rapidly and in a more definite manner than without the addition of the starter." In other words, the starter is the active agent involved in ripening the cream.

Starters are of two kinds, commercial and natural, depending upon the method by which the bacteria are obtained.

The Commercial Starter.

Starters prepared by various commercial firms, where facilities are provided for careful bacteriological work, are known as commercial or pure culture starters. They usually contain but one species of germ and this one selected from many others for its peculiar butter making properties. To be a good starter, the culture must develop at ordinary temperatures, 68 degrees to 70 degrees F.; it must produce acid rapidly and in quantity sufficient to allow of exhaustive churning; and it must be capable of producing substances which will impart to the butter the desired flavor and aroma. The bacteriologist, who prepares these cultures, has all of these points in mind when selecting a specific germ, and for this reason more uniform and satisfactory results are to be obtained with the commercial starter than with the home made or natural starter which is apt to contain germs, good, bad and indifferent.

The cost of these commercial products is so small in comparison with the benefits to be derived that their more general use is to be recommended. The initial cost of a starter is about fifty cents and by careful handling it can be propagated for an indefinite time. They are for sale under trade names such as Butter Culture, Flavorone, Lactic Ferment, etc., and can be procured directly from the manufacturer or through any drug store.

(1) Hastings: 181, Wisconsin Exp. Station.

Propagation of the Starter.

Commercial starters are put up by the different manufacturers in two forms, one a powder and the other a liquid. Inasmuch as extreme care has been exercised in their preparation to keep them free from contamination, it is important that they shall not be opened until ready to be used. This suggestion is offered since a person with the average curiosity would be tempted to open the bottle and taste or smell the contents, and in so doing expose it to dust and air contamination.

The first step in the propagation of the starter is the preparation of what is known as the "mother starter." One quart milk bottles are very convenient vessels for this part of the work. Some suitable cover or stopper must be provided for the bottles; Bushnell and Wright (1) recommended a cotton batting plug, while Hastings (2) uses an ordinary glass tumbler inverted over the mouth of the bottle. It is also necessary to have some instrument for transferring portions of the mother starter to other bottles in order to perpetuate the culture. For this purpose, Bushnell and Wright recommend a cotton swab attached to a piece of heavy copper wire; Hastings prefers a silver plated teaspoon with a piece of well tinned wire soldered to the handle to give length.

Having procured a number of one quart milk bottles, they should be boiled thoroughly in water for thirty minutes and then allowed to drain in a clean place. Next, several of the bottles are two-thirds to three-fourths filled with fresh, clean, whole or skimmed milk, preferably the former, the spoon or cotton swab inserted, and the bottle finally stoppered with a firm cotton plug covered with a glass tumbler. The bottles and contents are now sterilized in flowing steam for thirty to forty minutes on three consecutive days in order to kill the bacteria present in the milk. This sterilizing may be accomplished in a specially constructed steamer or in an ordinary wash boiler provided with a false bottom or shelf on which to set the bottles. Such a device is described fully by Bushnell and Wright (1). A common kitchen steamer will serve fairly well, provided it is high enough to admit the bottles and still permit the lid to fit down tight. Some authorities believe that better results are obtained when the milk is sterilized on one day only instead of three, their reason being that the prolonged heating injures the milk for starter purposes since the lactic acid germ thrives best in milk which is heated less. The only advantage in heating the milk three days is that it is rendered absolutely sterile, while one day's heating would not destroy the resistant spore forms of the bacteria which might be present, and which, if allowed to develop in the mother starter, would spoil it for that purpose. This would be true especially if several bottles of milk, were steril-

(1) Bushnell and Wright: Bul. No. 246, Mich. Exp. Sta.
(2) loc. cit.
(1) loc. cit.

ized ahead. If the three day sterilization is employed, the bottles should be kept in a warm room between each sterilization to hasten the development of the spores into the vegetative forms, which are more easily killed by heat. If the one day sterilization is adopted, all the more care must be taken in selecting clean milk since the fewer the bacteria present, the more efficient will be the sterilization.

Add the entire contents of the bottle of culture obtained from the manufacturer to one of the bottles of sterile milk and shake it gently for about five minutes so as to distribute the culture uniformly through the milk. Allow it to develop at a temperature of 75 degrees to 85 degrees F. The milk will become soured and curdled into a solid mass in from 18 to 24 hours and in this condition is known as the "Mother Starter." It is now ready for use in building up the starter proper, to be employed in ripening the cream. But before taking this step, a small portion of it should be transferred to a second bottle of sterile milk either with the teaspoon provided or by simply carrying over the cotton swab to the new bottle and allowing it to remain there for use the next day. In this way a second mother starter is prepared for the following day. In making the transfers from one bottle to another, the bottles should be left open to the air only long enough to make the transfer and then closed at once. If this precaution is not taken, there is great danger of contamination by air bacteria which would result, probably, in the starter going "off flavor." New mother starters should be prepared in this way every day whether they are to be used or not, since the activity of the lactic acid bacteria decreases rather rapidly if this is not done.

A good mother starter should appear smooth, glistening, firm and free from gas holes or free whey. It is always desirable to examine the ripened starter for flavor, odor, and acidity. This should be done by pouring a small quantity from the bottle into a clean cup, rather than by dipping any utensil into it which might be the means of introducing undesirable germs. The starter should have a clean taste, that is, it should be free from any disagreeable flavors; it should have a pleasant odor and should be only slightly acid.

Preparation of the Starter Proper.

The milk for this purpose should be selected for its purity and must be pasteurized by heating it for thirty to forty-five minutes at a temperature of 150 degrees to 160 degrees F. Cool this milk to 75 degrees to 85 degrees F. before adding the mother starter.

To forty or fifty parts of pasteurized whole or skimmed milk, add one part of mother starter. Let this stand for 18 to 24 hours at room temperature, 68 degrees to 70 degrees F., when it will be curdled; stir it thoroughly and it is ready to be added to the cream as a starter. The starter should be used at the time it contains the greatest number of active organisms. If too much acid is developed, the bacteria are killed, and to this fact is due the bad effects of over

ripening. The amount of acid which should be developed in a starter is from 0.6 to 0.7 per cent. for at this time it contains the largest number of active bacteria. Another way of judging is by the thickening of the milk which usually takes place at about 0.7 per cent. acid when the temperature is 65 degrees to 70 degrees F.

Ripening the Cream.

For every ten gallons of cream, use from one to two gallons of starter, or, in other words, from ten to twenty per cent. The exact amount can not be stated definitely, as much depends upon the age, acidity, temperature and thickness of the cream, of which the dairyman must be the judge. The cream should be sweet and as fresh as possible when the starter is added, and as much starter should be used as can be handled conveniently. In warm weather either ice or pasteurization must be resorted to to keep the cream sweet from one churning to the next, or else the churnings must be more frequent. Too much must not be expected of a starter, for while it may improve the quality of butter made from old, stale cream that has soured, it gives the best results when used with fresh sweet cream. A temperature of 70 degrees F. should be maintained during the ripening which is completed when the cream has acquired an acidity of 0.5 to 0.6 per cent. Under favorable conditions, this will require from six to eight hours. During this time, the cream should be stirred frequently to insure uniform ripening.

In regard to ripening, Rasmussen (1) says, "It should be considered that too sour cream, as a rule, gives a butter with a strong flavor and with poor keeping qualties and, therefore, the danger of getting the cream too sour before churning is greater than not getting it sour enough." In the absence of any chemical means for determining the per cent. of acid present, the only alternative is experience in judging the ripeness by the taste, aroma and appearance. As a general thing, "cream is ready to churn when it has a mild but distinctly sour taste, not too sharp or bitter, and has a glossy brittle appearance."

Pasteurized Cream.

During recent years, the pasteurization of cream for butter making seems to be gaining favor in our best creameries. In fact this practice has become almost a necessity in those localities where cream of all kinds is gathered from various sources. The butter maker has come to realize that if he is to have control over his finished product, so that he shall have some assurance of the constant and uniform quality of the output, he must resort to means by which he can eliminate the variable factors in his cream, namely, those undesirable bacteria and disagreeable flavors which will develop later on and make their presence manifest in the finished article. By heating the cream

(1) Bul. 141, New Hampshire Exp. Sta., 1909.

from 170 degrees to 180 degrees F. and *cooling it at once* nearly all of the bacteria are destroyed and many of the objectionable odors are driven off. If a starter is added to pasteurized cream, the lactic acid germs are given a comparatively free field in which to work and exert their beneficial influence. "This (1) method of ripening has a number of advantages over the use of unheated cream. It gives the maker full control over the ripening for by the process of pasteurization most of the bacteria are destroyed, then by the use of the pure culture, the same type of ripening, is assured and a uniform product results, a product that is uniform from month to month."

Kinds of Commercial Starters.

As stated before, commercial starters are put on the market in two forms, liquid and dry. The liquid cultures are usually prepared by inoculating a bottle of sterilized milk with the lactic acid germ, and when received by the purchaser, it has the appearance of sour milk which is exactly what it is, differing, however, from ordinary sour milk or natural starter, in that the curdling in this case has been produced by a pure culture. The liquid cultures are not as long lived as the dry forms and deteriorate more rapidly because of the harmful action of the lactic acid present upon the lactic germs.

The dry starters which are sold in the form of a powder are made by mixing a large quantity of starch, milk sugar or powdered milk with sterilized milk, soured by the lactic culture and the mixture subsequently dried at a low temperature. In this condition, the germs can not grow, but lie dormant, the organism being able to withstand dessication for a considerable period of time. In this state, no lactic acid can be produced, and its injurious effect is eliminated. For this reason the dry starters will keep much longer than the liquid ones.

Most dairy supply houses carry these starters in stock, but starters, like eggs, are better the fresher they are, and for this reason it is usually safer to send directly to the manufacturer, than to depend upon the old stock in the supply house.

A list of some of the manufacturers of commercial starters is given below:

Elov Ericsson,
60-62 E. Fifth St.,
St. Paul, Minn.

Parke, Davis & Co.,
Detroit,
Michigan.

Chr. Hansen's Laboratory,
Little Falls,
New York.

O. Douglas Butter Culture, Co.,
68 Northampton St.,
Boston, Mass.

(1) Flavoroue: Parke, Davis & Co., Detroit, Mich.

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ARSENICAL POISONING OF FRUIT TREES

BY

Wm. P. HEADDEN

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ARSENICAL POISONING OF FRUIT TREES

In Bulletin 131 of this Station, issued in July 1908, were recorded the results of our studies to determine the cause of the death of many of our apple and pear trees. Professors Paddock and Whipple had addressed themselves to this subject for some years, and were unable to satisfy themselves that any of the well known causes usually producing the death of trees could be appealed to as the actual agents in these cases. Mr. Whipple, now professor of horticulture in the Montana Agricultural College, had sought for fungus and bacterial troubles in vain. The results of our observations forced us to the conclusion that the cause was not to be sought in the soil per se for to quote Prof. Whipple's words, "Soil conditions seem to have no relation to the disease, as it is found on all kinds of soils."

While I recognize the fact that it is necessary to control the insects injurious to our crops, I have entertained grave misgivings in regard to the ultimate effects of spraying arsenic on our trees and soils and when the other members of this Station, men thoroughly competent to determine the facts, found none of the causes usually producing disease in trees present in these cases, I became more deeply impressed with the probability that the trouble was primarily due to the action of the arsenic applied to the trees as a spray. I gave in Bulletin 131 a definite experience with a case in which it was charged that arsenic, lead and copper had been the cause of the death of trees, grass and even of animals eating the grass, and I am fully convinced that

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AN EXPLANATION.

In Bulletin 131, Arsenical Poisoning of Fruit Trees, I did not give the location of any orchard or the name of a single owner, nor have I given either in the following pages. My reasons for this are the following: I think that it would be a gross injustice to the owner of an orchard to publish a statement of his misfortunes or unwise practices throughout the state and nation by means of an Experiment Station bulletin. If the statements made are all true, it only makes matters worse rather than ameliorates them. Unscrupulous neighbors might take advantage of such statements to do the party named injury. I have been treated kindly by the orchardists in connection with this work, however, I understand that I have been the innocent cause of injury. The fact that I was interested in the study of an orchard problem, not arsenical poisoning, was made the basis of dishonorable representations which did the owner a serious financial wrong. It would, in my estimation, be wholly unpardonable to name the properties of men who have given me aid in this investigation when I know that it would be doing them an injury and requiting kindness by inconsiderateness and ingratitude. I have not, in any way, concealed or distorted a feature of the problem, but I have purposely used examples from different sections and different orchards in order that I might present the whole case—but by no means all of the different facts—without doing anyone an injury. If I have succeeded I shall be pleased, if I have failed I can only regret it.

W. P. H.

there is great danger of our adding arsenic enough in the form of materials used for spraying to jeopardize not only the life of the trees but bring about other conditions of a most serious character.

I have heretofore been very careful not to condemn the practice of spraying, but simply to call attention to the dangers accompanying the practice and particularly the excessive, even irrational, application of these poisonous preparations to the trees and eventually to the soil. If the soils themselves already contain arsenic enough to pass into the plant system it makes the application of more arsenic only the more ill-advised.

Up to the present time we do not know of any other practical and effective means of protecting our fruit against the codling moth than some form of arsenic, and so far as we now see we must continue to use this means. This, however, does not mean that we cannot improve the practice in several ways. It has been demonstrated that a much smaller amount of arsenic may be used than has heretofore been customary, with most excellent results. Prof. Gillette showed several years ago, that 95 per cent. of the protection given to a crop when three or four sprayings were made was effected by the first spraying. His investigations have shown that a single spraying, thoroughly well done, will produce clean apples unless there is some local source, an adjoining unsprayed orchard, from which moths may migrate and infest the orchard anew. There is another way of improving our practice, namely, by using a form of arsenic more insoluble in water than the forms now used and which will change but slowly into a soluble form in the soil. We have considerable reason for hoping that the sulfid of arsenic may be used with benefit in this direction. A still greater improvement would be to obtain some substance which would furnish our fruit the desired protection, but which would be entirely free from the serious objections which apply to the use of any arsenical preparation. This is not an impossibility, as indicated by the report of experiments with nicotine made by Prof. Gillette to the American Association of Economic Entomologists, at its recent meeting in Boston.

The assumption that the arsenical preparations used for spraying are insoluble in water is not justified, and yet this is a condition which they must fulfill in order that thay may be safely used. Further conditions may, and in some cases certainly do, exist in the soil which makes them more soluble than they are in pure water. I have met with many men to whom it was a matter of some surprise that the arsenic might accumulate in the soil, though they knew that they were spraying a number of times annually and that the amount of soluble arsenic in the soil might increase with the years.

Bulletin 131 states that this line of work was a direct outgrowth of my attempt to study the alkalis of the state. It was then thought that it was rather more than probable that the abundance of these salts in some of our soils had produced an exaggerated effect of the arsenic on our trees. There may be some truth in this view but I am now of

the opinion that the effect of the alkali has been nothing more than to increase the action of the arsenic and has not been the cause of it. I am led to modify my views in regard to the importance of the part played by the alkalis because I have found cases of corrosion by arsenic under conditions which preclude their action. This in no way contradicts any facts established in regard to the adequacy of sodic chlorid or carbonate to bring arsenic in solution when present in the form of lead arsenate, calcic arsenite or as Paris green, but simply adds the fact that trees may be attacked in soils practically free from these salts, indicated collectively by the term alkalis.

The result of my study of this subject during the past year has strengthened my conviction that the conclusions presented in Bulletin 131 were not only fully justified by the facts presented, but were very conservative and I do not see any reason to modify any statement by making it less general or in any way milder. I have, furthermore, learned of no fact indicating any reason for altering the previous findings of Professors Paddock and Whipple. These gentlemen did their work thoroughly and with that conservatism demanded of the really scientific worker. In the following pages we shall present some new facts but they will in the main be a re-presentation of the main points set forth in Bulletin 131

In the bulletin just referred to three phases of the question were set forth: First, the corrosive action of arsenic which had already collected about the crown of the tree, and designated as local irritant poisoning; Second, the action of the arsenic which had been taken into the system of the tree and designated as systemic poisoning; Third, the action of lime, showing that it probably exercised a toxic action either alone or in conjunction with the arsenic. The possible action of both copper and lead is freely admitted, but that of the arsenic is candidly considered as clearly the most important one and these two are scarcely more than mentioned for the purpose of admitting the possibility of their exercising some influence.

The most striking effects upon the trees are produced by the corrosive action of the arsenic on the crown and roots, and this form of the trouble is the one which forces itself mostly upon the average man.

Description of the Trees.

The effect of the arsenic does not express itself in the appearance of the tree till its action has gone so far that the death of the tree is very near. The first general signs of trouble are an early ripening of the foliage the first year followed by heavy blooming and usually an abundant setting of fruit the second. This fruit is seldom matured as the tree usually dies in late summer or early fall, the fruit and leaves remaining on the tree. In the case of pear trees, the foliage is mostly of a deep purple on the badly affected trees while that of healthier trees is still green. An examination of such trees reveals the following con-

ditions, the bark of the crown has been completely disintegrated and almost always that of the roots next to the crown. Its structure has been wholly destroyed and the woody tissue beneath has been stained brown. In bad cases its structure too has been destroyed so that under the rasp it often acts as though thoroughly charred, outwardly it is often blackened. The bark of such trees is usually a reddish yellow frequently showing longitudinal cracks. The woody tissue of the lower portion of the trunk is stained brown though the tree may still be alive. This is shown in Plate 3, Fig. 3, p. 14, Bulletin 131, which is a portion of the lower part of the trunk of a Ben Davis tree dug up when in full bloom. The bark on this portion of the tree was intact and the staining was not due to dead wood exposed to the air.

The Yellowish-Red Bark Not Diagnostic.

The yellowish-red color of the bark of the limbs and twigs of such trees is probably the result of malnutrition rather than of the direct action of the arsenic and while this color is very commonly present in cases of this trouble, I cannot consider it as a diagnostic feature.

The Point of Attack in Cases of Irritant Poisoning.

The attack on the bark is evidently made from the outside because we find patches on some of these trees where the girdling is not yet complete and while the outer portions of the bark may be disintegrated the inner portion may be apparently entirely healthy. There are no signs in such cases that the bark has ever been raised or loosened from the underlying tissues. These facts necessitated the examination of trees in which the trouble had not advanced to this stage. Samples were easily found showing all stages of the progress from the incipient attack in which the disintegrated bark formed only a very thin layer on the outside to those in which it had finally perforated the bark and attacked the underlying wood. In some orchards we find some degree of this girdling on almost every tree. I have in mind at this writing a pear orchard, containing possibly 300 trees, in which I failed to find a single tree which did not show this corrosive action of arsenic in a marked degree and in many cases the bark had already been perforated.

The Roots.

The above remarks apply to the roots especially at their juncture with the trunk; sometimes we find the whole of this portion of the root involved, again only the upper portion, if the attack has not approached very near to the final stages. On the roots we often find a very sharply defined limit to the trouble just as we usually do as we approach the surface of the ground. The distal portion of the roots are as a rule in better or even good condition. This point was well illustrated by the case of a pear tree root which I dug out. The root was entirely dead near the trunk, but was apparently healthy a few feet away and had thrown up sprouts.

The Trunk of the Tree.

The trunk frequently shows no effect of the trouble above the ground, especially is this true of the pear trees. Apple trees sometimes show, in such cases, chocolate brown spots on the trunk of the tree. On removing the bark, its inner side beneath these spots, as well as the underlying tissues, present a mottled appearance. The cambium layer is, in these cases, not darkened or discolored except in these spots; the bark is not loosened or at this time dead but it soon dries down to the wood. These areas often have an offensive odor.

The Varieties Affected.

The varieties of apples and pears in which we have found this trouble are so numerous that it is scarcely feasible to name them. Some varieties appear to be more sensitive in some localities while some other varieties are more generally affected in other localities. Mr. Whipple noted the fact that the Ben Davis and Gano are very sensitive to arsenical sprays. It is apparently a fact that in some localities these two varieties are more generally affected by this trouble than any others, in other localities this is not at all true. This statement can of course be made of the other varieties.

The Influence of the Age of the Tree.

Orchards which had attained a considerable age before any arsenical sprays were applied to them do not seem to show the effects of the arsenic to the same extent as those orchards in which the trees were younger when the first applications were made. I recall an orchard visited in company with Prof. Gillette, in which there were trees of very different ages, the most of the trees being of the first setting, now between 25 and 30 years old, but a few of them were much younger. We found none of the old trees which seemed to be in danger from this trouble, while several of the young trees were about to succumb to it. This by no means proves that old trees are wholly exempt, for I know of trees 30 years old or older that have been killed by this trouble. In one orchard a part of which is 25 to 27 years old, the rest about 14 years old, the older portion contains only a few affected trees, while there is quite a number of such in the younger orchard.

The Influence of the Soil.

We will make some general statements at this time, which while entirely adequate for our present purpose are not intended to cover specific features of the problem. Mr. Whipple's statement "Soil conditions seem to have no relation to the disease, as it is found on all kinds of soil," seems to be wholly justified. I have found it literally "on all kinds of soil." While the character of soil may modify the trouble, it does not determine it. I have found orchards set in most excellent loamy soil, well drained, irrigated with pure water, in-

telligently cultivated, and well located in respect to protection against severe weather and yet this trouble was exceedingly prevalent, while in other orchards on less desirable, even on bad soil, this trouble, though present, was by no means so prevalent. In other cases the problems presented were so involved that no student of this subject would undertake to unravel them. I am fully convinced that the soil itself does not produce the trouble under discussion.

Do Salts Other Than Arsenic Produce It?

The answer is a negative one. We have very marked cases of trees having been killed by the presence of excessive amounts of nitrates formed in the soils. I described some of these at the meeting of the Society for the Promotion of Agricultural Science in Portland, Oregon in August, 1909,. The action of the nitrates is wholly different from that of the arsenic, neither the crown nor the roots are corroded but the foliage and the tree are killed outright, sometimes within a few days. The attack expresses itself wholly differently, it is not gradual, but as above stated sudden, there is no ripening of the foilage but a strong burning and killing. The bark of the crown and the large roots at the time of the attack is perfecly normal in appearance in cases not complicated by pre-existing troubles.

I have found no conditions under which any trouble can properly be attributed to the presence of any excess of sodic chlorid. I have endeavored to determine the effect of sodic chlorid by direct experiment. It is beyond question that salt, in excessive quantities, is injurious to apple trees, but excessive quantities, according to our results, would mean very many times as much salt as we find in any of our soils. Its action was very moderate and expressed its only visible effect upon the leaves much in the same manner as the nitrate.

There is no carbonate of soda, worthy of mention, in our soils, so the action of this salt is eliminated from the question.

There is in some cases a rather large amount of sulfates (sodic, calcic, and magnesic) present but the action of these is not corrosive. Their action is so mild that seedling plants grew in soils to which I had added as much as two per cent. of the weight of dry soil of sodic sulfate and even the little seedlings were not corroded or injuriously affected. I have made a similar experiment with magnesic sulfate. These experiments were made years ago when the opinion prevailed that the alkalis were prejudicial to our lands. These experiments are in keeping with the fact of common observation in many parts of the state, i. e., the production of good crops on lands so rich in alkalis that a heavy incrustation covers them under conditions favorable to its formation. I know of very healthy orchards on land rich in these salts.

Is the Trouble Produced by Excess of Water?

This question is likewise to be answered in the negative. We know that we can destroy even pear trees by keeping their roots sub-

merged in water but this is a condition nowhere obtaining among all the cases studied. The prevalence of this trouble in orchards on high, well drained lands is a sufficient answer to this.

The Area Involved.

In Bulletin 131 I stated that the principal orchard growing sections of this state were probably involved. It is now certain that the extent is wider than the boundaries of this state. There is no disposition on my part to seek consolation in the fact that I believe many sections of the country to be suffering, in a less degree I hope, from the same ills.

The Number of Trees Affected.

Under this caption in Bulletin 131 I stated that it would be difficult to obtain data on which to base even a rough estimate of the number of trees suffering from this trouble. I have visited many orchards since I wrote the above statement and am now convinced that it is difficult to find a fifteen-year old orchard in the state wholly free from this difficulty. There are probably a few but not many. I know of an orchard, the owner of which said to me: "I must have a thousand sick trees." I think that this was an overestimate, but it serves to convey a definite idea of how very prevalent the trouble is in some orchards. I have seen a pear orchard in worse condition even than this apple orchard. Both of these orchards, though many miles apart and on very different land, are within this state. I have not visited the apple growing sections of the southwestern portion of the state and so do not know the condition of affairs there but in the rest of the state no section is entirely free from this trouble. It is found in Larimer County as well as in Otero, Fremont, Delta and Mesa counties, and this represents a distance of nearly 350 miles from east to west and 200 miles from north to south. I am convinced that the number of trees already seriously affected by this trouble are not numbered by hundreds, but rather by tens of thousands.

This may not be an inappropriate place to state again, as I stated in Bulletin 131, that publication on this matter was not the result of any sudden impulse, nor of any desire to obtain a certain notoriety by creating suspicion and alarm in the minds of any class of orchardists, much less to protest against the general practice of spraying, but the publication was made simply because I was fully convinced of the sufficiency of the proofs that great injury had already resulted from the practice, particularly from the irrationally ultra manner in which the practice has been carried on, and that it was perfectly proper and right that the truth should be made known. The facts were presented conservatively. My colleagues agreed that it was wise to publish the results as simple facts. This is what I did and this is the only purpose that I have in view in the present bulletin.

Present Conditions in Regard to the Presence of Arsenic in the Soil.

Several questions relative to this subject may be raised such as the presence of arsenic in soils in general. Toxicologists have answered this in the affirmative, but the evidence of all is that it is present in minute traces. This is not true of our Colorado virgin soils, for they contain more than mere traces, which question will be discussed in a subsequent paragraph. The bearing of this fact on the question in hand is slight. The arsenic contained in the virgin soils examined, taken approximately to the depth of one foot, is just about one-tenth of the average found in the orchard soils, excluding extremely high ones. The maximum amount found in a virgin soil taken to a depth of one foot is almost exactly one-twenty-eighth of the maximum found in an orchard soil taken to the same depth. The orchardist is not concerned with the source of the arsenic but with its effect upon the trees. If there is already a little arsenic in some of our soils, enough to be taken up by the trees to such an extent that its presence may be shown, it does not argue that we do no damage by increasing this amount from 10 to 28 times.

Another suggestion is that the water used for irrigating purposes may contain arsenic. It is a fact that some spring waters contain minute traces of arsenic, so small, however, that its presence may best be established by examining the deposits from such springs. It is, however, not true of our river waters, so far as my knowledge goes, and if it were true, the quantity usually carried by spring waters, not river water, is so small as to be utterly insignificant in comparison with the quantities which we have been pouring upon our lands.

We have been using arsenical sprays in the various parts of our country for various purposes about 40 years. We have been spraying our apple orchards about 28 years and in Colorado we have been spraying 18 or 20 years. The question is what has been the effect of this in regard to the amount of arsenic in the soil? The answer is given above, i. e., that, even in Colorado, we have increased the arsenic content of our orchard soils at least ten fold and in the older states it must be even worse if they have been nearly as zealous in spraying as we have been. But few people consider the real character of the sprays used and we cannot expect the ordinary orchardist to consider the possible results and there has been an abuse of the practice. The practice in this sense has been a dangerous one. I do not know that any station has ever advised six, eight or even nine sprayings in a season. Three is the maximum recommended by this station, and yet I know of men who have sprayed nine times in one season according to their own statements; four, five and six sprayings are still applied by some. The amount of arsenic used has also been unreasonable in many instances. I have in mind a man who, having been directed to use one pound of arsenious acid to the tank added one and a quarter pounds, and applied 90 gallons or a little over 0.56 pound of white arsenic to each tree during the season. I know another man who used almost exactly the same quantity of spray, 90 gallons to the tree, using

16 pounds of lead arsenate to the tank. This man claimed that this was his custom. Assuming this statement to be literally true, let us see how much arsenic acid he had applied to this orchard per acre in the six years preceding. As stated, he used 16 pounds of arsenate of lead to the tank and applied 90 gallons to each tree during the season. Assuming that the pasty arsenate of lead was one-half water it would give us eight pounds of dry arsenate of lead to the tank, 0.04 pound in each gallon of spray and as he used 90 gallons to each tree he applied 3.60 pounds of dry lead arsenate, or if the dry lead arsenate contained 25% of arsenic acid, he added 0.9 of a pound of this acid to each tree or 72.0 pounds per acre each year counting 80 trees per acre. In six years he would add 432 pounds arsenic acid to each acre of his orchard, which if evenly distributed through the first foot of soil would give 108 parts per million. This calculation is much nearer to the facts in the case than such calculations are apt to be, for I found 61.33 and 128.83 parts arsenic acid per million in the upper portions of this soil. The other man who used 1.25 pounds white arsenic to the tank, said to me "you don't realize how heavily I have sprayed. This ground was all white with it." I do realize that he sprayed heavily, but he does not. He was adding arsenic acid to his soil at the rate of 51.84 pounds per acre per annum or taking it for a period of six years, as in the preceding case, he added 310 pounds per acre, or 77.5 parts per million of soil. The latter of these men used 26 times and the former 36 times as much arsenic as we now know would have sufficed to have assured them a crop with not more than 5 per cent. wormy apples. These men have lost a number of trees from this cause.

The Amount of Arsenic Now Present in Our Soils.

Determinations of arsenic in our orchard soils have indicated the following range; 25.5, 26.0, 30.6, 36.8, 38.2, 39.9, 61.3, 128.83, and 137.99 parts arsenic acid per million. The samples were taken, some from about the base of the tree and others out under the heads of the trees and to depths varying from four inches to one foot. The soils here represented are without exception desirable ones, they are free from seepage and alkali, and are well supplied with water. These orchards receive good care, still there is more or less of the trouble described as arsenical poisoning in each of them and some of them are very badly affected.

That the arsenic should accumulate in the soils is what we would expect. The materials used as sprays are not very soluble in water. The amount of water applied to our soils is not excessive, irrigation waters and rainfall together amounting to not more than 24 inches. The materials are not volatile and the evolution of arseniureted hydrogen from the soil has not yet been proven, though a slight elimination of the arsenic in this form, especially under favorable conditions, might take place. The fact, however, is exactly what we would

anticipate, i. e., that the soils of orchards which have been sprayed for some years are already rich in arsenic.

Some of This Arsenic is Soluble in Water.

In the application of the sprays it was soon found that the arsenic must be insoluble or it would burn the foliage of the trees and in order to avoid this an endeavor was made to obtain a compound so insoluble that this effect would be avoided. To this end lime was added to the Paris green, and the lime, sal soda and arsenic preparation recommended. I do not know whether any consideration of the final effect of the arsenic on the tree was considered or not. The insolubility of the spray material is the only protection that our trees have had. The term insolubility as here used means nothing more than difficultly soluble and that in a somewhat popular conception of the term. The spray materials used are somewhat soluble in pure water and much more readily so in solutions of sulfate and chlorid of soda. The Kedzie formula was supposed to remove the whole of the arsenic from the solution because of great excess of caustic lime, but this is readily changed into a neutral salt, the carbonate, when its protective action is practically destroyed, besides there remains a considerable amount of arsenic in solution owing to the solubility of the lime salt. Paris green to which the proper amount of lime has been added yields arsenic rapidly to water, and arsenate of lead, $Pb_3(AsO_4)_2$, will yield 0.3% of its dry weight of arsenic acid. Soil, therefore, which contains these spray materials ought to yield arsenic to pure water and it does. I at first assumed that the presence of so much carbonate of lime, as is present in our soils, would wholly prevent any arsenic from going into solution, but this is not the case. Another agent which I thought would also tend to prevent the solution of arsenic is the iron which is fairly abundant in our soils, especially our red soils. A very large number of our soils are marly, namely, contain more than 5% of calcic carbonate, but neither the lime nor the iron nor both together prevent the solution of arsenic in our soils. This is an easily established fact. Sixteen samples of orchard soils from various parts of the state have been tested and found to carry very decided quantities of arsenic which is soluble in water. I have weighed the arsenic in a few instances and obtained the following figures: 0.68, 0.68, 0.84, 1.04, 1.166, 1.265, and 1.345 parts of arsenic acid per million of soil. These quantities corroborated by those obtained with nine other samples are conclusive in regard to the presence of water soluble arsenic in the soil in very decided quantities and that, too, in quantities which competent experimenters have found to be injurious to vegetation when present in nutrient solutions.

When I wrote Bulletin 131 I feared that the presence of water soluble arsenic in our soils might be largely due to the presence of sodic sulfate and sodic chlorid. That these salts are present in our soils in larger quantities than in eastern soils is a well known fact. It has

been shown by experiment that lead arsenate, even the tri-plumbic salt, yields arsenic quite freely to dilute solutions of these salts and that calcic arsenite (lime, sal soda and arsenic) acts in a similar manner. It has also been previously stated that the arsenical compounds usually used for spraying are perceptibly soluble in distilled water. The statements made regarding this matter in Bulletin 131 are perfectly correct and I do not wish to change them except to lay less stress on the action of the alkalis, for soils entirely free from alkali contain water-soluble arsenic in weighable quantities. The solubility of the arsenic in the soil is undoubtedly favored by the presence of alkalis, but is not primarily caused by them.

For some years past, since about 1904, we have been losing a number of pear and apple trees by an affection which men, competent to determine the facts, have been unable to establish as due to any other cause than the corroding effects of arsenic. Among the causes considered were bacteria, fungi, King disease, winter killing, alkali, etc. The trouble is independent of the varieties of soil, it expresses itself uniformly in the same manner, attacks the trees at the same point, runs a very uniform course in regard to both manner and duration and is almost uniformly fatal. Here attention should be called to the fact that it has been only the badly affected trees that have been observed until very recently.

In regard to the soil we have shown the extent to which arsenic has accumulated in the soil due to the practice of spraying. Further we have shown that this arsenic in the soil is soluble in water to an extent that exceeds the limit of safety, and that the large quantities of lime and iron salts in our soils do not effectively prevent the solution of the arsenic by pure water. We have shown that the alkalis in our soils may favor, but are not needed, to cause the solution of this arsenic. We have also shown that our virgin soils, a goodly number of them too contain arsenic and will show in the proper place that this arsenic is slightly soluble in water in six out of seven cases.

The amount of arsenic present in our virgin soils, however, is less than one-tenth of that found in our orchard soils, and while it may play a part in some phases of this subject, it does not in any manner enter into the question of corrosive arsenical poisoning because it is associated with the marl and for the most part lies beneath the feeding area of the tree and is not collected about the crown of the tree.

The phase of arsenical poisoning under immediate consideration begins by attacking the outside of the bark at the crown of the tree converting it into a black, friable mass, finally eating its way through the bark, attacking the woody tissues and producing the death of the tree, either by starvation or otherwise, a question which the future may solve. The important fact is that the trees of which we are writing, and there are many thousands of them, are either doomed to die within the next two years or are already dead. That portion of

the roots joining onto the base of the trunk is almost invariably involved. The attack may, in a few instances, begin on the roots but the number of these instances is small.

The Effect of Arsenic on Trees.

I have a record of about twenty trees, the greater portion of which I have seen myself, that have been injured or killed by arsenic, either in the form of arsenious acid, sodic arsenite, calcic arsenite or lead arsenate.

In Bulletin 131, page 19, I referred to experiments of others made to establi h the effect of arsenic upon vegetation and gave the results of a few experiments made with greenhouse plants and cited the cases of two trees which I had met with, one of them presenting with great clearness the action of arsenic, particularly in the form of arsenious acid, upon the bark and woody tissues of the tree. I then stated that I gave the case in considerable detail because I believed it to present as conclusive an illustration of the action of arsenic upon trees as could possibly be adduced. I have since then seen several trees injured by the same cause, sodic arsenite, and while they each present an essential reproduction of that case, none of them have been any more marked or presented any feature more forcibly than it. I shall therefore use it again to show that soluble arsenical compounds when present in sufficient quantities will kill trees, secondly to show in some detail what the action of arsenic is on the tissues of the tree, particularly upon the bark and the woody tissues. The condition of this tree in the following April is shown in Plate I, taken from Bulletin 131.

The arsenic used in this accidental experiment was sodic arsenite emptied into an irrigation ditch, twelve feet distant from the tree. This was done in the month of June when the tree was in active growth. Two days later a portion of the tree was sick or dead, the person describing it said dead. I was not present that day. The limb never showed any signs of life afterward, the killing was thorough. Mr. Whipple and I subsequently dug out the poisoned root of this tree tracing it from the trunk to the point in the irrigating ditch where the arsenic had been emptied into it. The other roots of this tree which we encountered were apparently normal. Even those branches of this root which ran parallel to the ditch and whose feeding area had not received any of the arsenic also appeared normal. The rootlets within whose feeding area the arsenic had come were dead, being black and brittle. We could see the course of the arsenical solution from the rootlets to the tip of the twigs as the root lay in the trench which we had dug to expose it. The lateral branches of the root and the two side sections were normal in appearance, the top section and also the bottom section had been very strongly attacked. The bark of the root on the two sections attacked was thoroughly disintegrated and two irregular sections of the woody tissue of the root were killed and stained brown, shown in Plate II, Fig. I. The total

Colo. Ag. Expt. Sta.

PLATE I.

Fig. 3

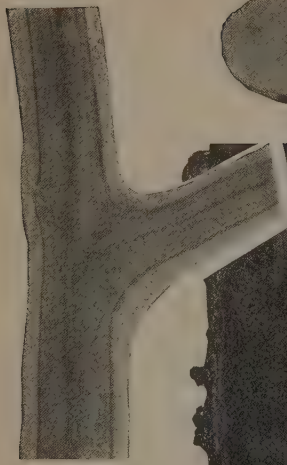

Fig. 1-A

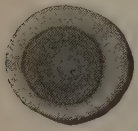

Fig. 2

Fig. 4

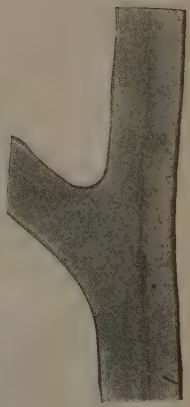

Fig. 1-F

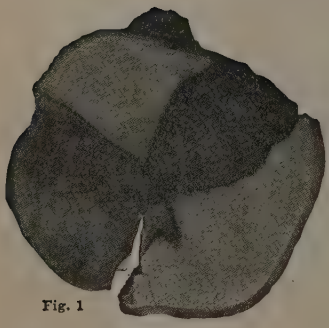

Fig. 1

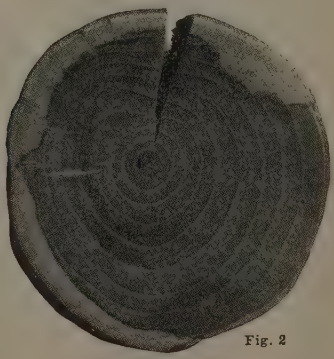

Fig. 2

Colo. Ag. Expt. Sta.

PLATE II.

disintegration of the bark on the root shown very distinctly in Plate II, Fig. 4, was continuous to the base of the tree. Here the bark became brown and sunken. This particular form of the injury extended some distance up onto the limb. Beneath this bark the wood was stained brown. The sunken part and stained wood is shown in Plate II, Fig. 2. The interior portion of the remoter branches of this limb was stained brown. This is shown on Plate II, Fig. 1-A, in longitudinal section, in Fig. 2 in transverse section. The other portions of this tree were perfectly normal, the bark was healthy, the woody tissues of both roots and branches showed no staining or "black hearted" condition. The healthy condition of the other roots and branches of this tree is also shown on Plate II by Figs. 1-B and 3. The so called black heart is in some cases caused by freezing but this case cannot be explained in this way, for we know its cause and can trace its course and action and the injury was done in the month of June. No one will, I think, suggest that these changes were subsequent to and a result of death and not of the action of the arsenic for all parts of the tree nourished by roots feeding outside of the poisoned area, even sections of this one root, remained apparently healthy and those portions of this tree which I have not cut off are still healthy.

I indicated clearly in Bulletin 131 that I was aware of the fact that this case, and all the cases do the same, raises questions regarding the course of nutrient solutions in the tree. I dismissed this whole subject with the following statements: "The course was direct and the flow of the poisonous solutions was confined to a comparatively narrow channel. * * * I am not concerned about any theory of sap circulation, but am simply tracing the discoloring effect of the arsenic through the roots into this portion of the branches."

I have personal knowledge of four other trees injured by the same agent, sodic arsenite, in a similar manner. The facts in these cases are even more interesting than in the preceding.

There had been fillers planted betwen the rows of apple trees. These fillers, plum trees, had been cut down, the owner poured one half teacupful of the sodic arsenite solution on each of the four stumps to kill them and at the same time get rid of the arsenical solution. No effect was produced for the next two or three days, at the expiration of which time the orchard was irrigated. The statement of the owner and his wife is, that within fifteen minutes after the irrigation water reached these stumps the leaves on one side of the largest of the four trees involved drooped and never recovered. The owner surmising the cause of the trouble dug a trench and cut off the roots of the tree on that side. The odor of the sap exuding from the wounds made on the limbs by the arsenic was very offensive.

The fourth tree in this group presented an interesting case. Two limbs on one side of the tree were injured, portions of them were killed. There was a narrow strip running from the ground up into a big limb of this tree and then divided, following two smaller limbs, breaking out to the surface in an apparently erratic way. The limbs were

killed. Not being fully satisfied about the facts connected with this tree, I determined to examine its roots. I found two roots affected, one was still partly alive, the other was entirely dead. Neither of these roots was very large, a scant inch in diameter, but we traced the wholly dead one for twelve feet then we trenched across its course at several points and thus traced its dead rootlets to the stump on which the arsenic had been poured, 22 feet from the trunk of the tree. These roots presented externally the same appearances as the root previously described and is well represented by Plate III. reproduced from Bulletin 131. The other roots of this tree which we encountered were apparently normal. I examined several samples of wood from the first tree and found arsenic abundantly present and determined the quantity of arsenic present in the woody tissue of the root. The amount of arsenic present in the woody portion of the root of the first tree after the bark had been pared off corresponded to 34.5 parts of arsenic acid per million parts of tissue. The arsenic in the root of the second tree described corresponded to 24.02 parts of arsenic acid per million parts of tissue. The disintegration of the root was certainly remarkable.

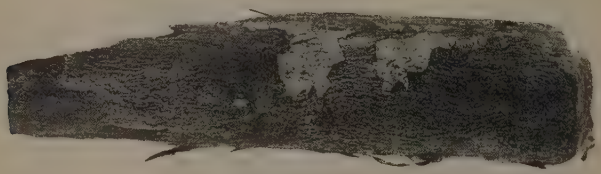

PLATE III.

I have information of several other instances in which similar results have been produced. According to the statements of the owners it seems probable that the arsenite of lime might have done the damage to their trees.

Mr. A. B. Hoyt, Horticultural Inspector of Mesa County, informs me that he has seen a cottonwood and a willow tree killed by the bursting of a jug of sodic arsenite which had been left beneath them.

I have the record of some other trees killed in a similar manner.

These cases are cited that we may present the effects of arsenic upon the tree and its tissues when it is present in the soil in a soluble form and in sufficient quantities to kill quickly.

We find in these cases the following features: the disintegration of the bark and woody tissues of the roots, the killing of the bark and tissues of the trunk, the production of a black heart, the exudation of ill smelling juices and a stunting in cases where a portion of the limb has survived.

The arsenite of soda mentioned above is the solution of white arsenic in sal soda, and is mixed with lime and water before it is used as a

spray. It is mixed with lime to make the arsenic insoluble, though a very marked quantity of arsenic remains in solution in the alkaline liquid. This is contrary to general belief. I have had two lots of this preparation made with very excessive quantities of lime. Two hundred cubic centimeters of the supernatant solution gave a good test for arsenic by Reinsch's test. The sodic arsenite is not itself used for the purpose of spraying the trees but is added to the milk of lime to make the lime, sal soda and white arsenic preparation.

Dr. S. M. Bradbury, Horticultural Inspector of Mesa County for eight years, makes the following statement which is used with his permission. "Bands had been used in a certain orchard and on adopting the lime, sal soda and arsenic spray these bands were left on the trees, some of them for two or three years. Some of these trees died and on examining the bands we found that the bark beneath the bands had been entirely eaten up. The lime and arsenic had collected under the bands and destroyed the bark."

I know of another tree within a few feet of which the owner had mixed his spray material for several years in succession. This tree died and its wood was rich in arsenic. In this case arsenate of lead was used as far back as I have any information—about four years before the death of the tree.

I will cite but one more, though there are a few other instances which might be given. A man emptied his spray tank, containing arsenate of lead, about six feet from an apple tree; that side of the tree died. I did not take and analyze any portion of this tree because the owner did not wish me to deform the tree as he was sure he could cure it. The effects in these cases were in the main the same as in the cases killed by sodic arsenite, disintegration of the bark, the staining of the woody tissue, the production of a "black heart," and the production of a yellowish red bark frequently with longitudinal cracks. It will be remembered that I did not see the trees described by Dr. Bradbury, though I know the orchard very well and can testify that it has been in very bad condition for several years past. His description which I believe to be entirely reliable tallies exactly with what we find in the other instances. It is only through accidents that we have opportunity to observe the effects of sodic arsenite on 16 or 18 year old trees in commercial orchards, but the lime arsenite and the lead arsenate have been applied plentifully to our commercial orchards for years past and the action of these two may be found in almost any commercial orchard from 12 to 18 years old. No distinction can be made so far as I have observed between the action of these two sprays, except that the lime salt being more readily soluble than the lead salt probably has done the greater amount of injury to our orchards.

We have then a fair amount of evidence obtained by direct observation of the effect of arsenic in the three compounds, sodic arsenite, lime, sal soda and white arsenic, and lead arsenate, upon the bark, the woody tissues and the life of the tree. The sodic arsenite acts quickly, causing the death of all parts of the tree to which it may be carried; it causes the disintegration of the bark, especially of the

roots, and may also destroy that of the trunk. It stains the woody fibre and causes its disintegration, sometimes producing a punky condition, and produces in the branches not so seriously affected a "black heart" condition. The lime arsenite and the lead arsenate produce essentially the same condition in the tree but their action is very much less intense.

Is Arsenic a Normal Constituent of Any Wood?

I have not examined many woods for arsenic with the object of determining this point, one sample of oak and a few apple trees. The oak contained no arsenic and I have found three apple trees in Colorado which were free from it, two of them were young trees and the third tree was one which had been killed by blight. The presence of arsenic in fodders, vegetables, meats and even in the human body are matters which belong in the province of the toxicologist and have but little bearing on a question dealing with such large quantities of arsenic as we do in studying its effect upon trees. I think that we are justified in assuming that normally arsenic is no more a part of an oak, an elm, or an apple tree than it is of the human body. In these days, however, when arsenic is spread broadcast upon our soils as superphosphates and arsenical sprays it would be rather surprising if it has not become so generally distributed that it might be found in the organs and bones of almost any person. I am certain that should the writer of these lines die suddenly and his body be subjected to a careful analysis, but little trouble would be met with in demonstrating the presence of arsenic in his liver, spleen, and possibly other organs, of which facts I hope to give good proofs in a later paragraph. I think that we may waive the question of traces and assume without any fear of being in error that arsenic is not a normal constituent of apple and pear trees in the quantities with which we are dealing, from one half to upwards of 20 even to 34 parts of arsenic, calculated as arsenic acid per million of the woody tissue.

Arsenic is Taken Up by the Trees.

I have endeavored to convey to the reader a clear notion of the amounts of arsenic which have accumulated in our orchard soils. As much as 138 parts of arsenic, calculated as arsenic acid, having been found per million parts of soil. This does not mean that every man's orchard soil is as rich as this nor does it necessarially follow that I could not have gotten samples from this orchard which would have run less, or perhaps more. This sample was a large one taken to the depth of one foot. I have shown that the water soluble arsenic in these soils in some cases exceeds 1.25 parts per million. The effects of soluble arsenical compounds on apple trees has also been shown. These cases were extreme ones, it is true, but they prove that apple trees may be killed by arsenic and they show the action of arsenic on the bark and wood of the tree. We will now give in

some detail what we find in the case of our sick trees. No one can tell how many sick trees we have. I have examined several thousand, however, and in stating this it is to be understood that no trees suffering from neglect or blight or sunscald or nitre or trees in which there was any evident complication of troubles or even mechanical injuries are included.

Plate IV. is a photograph of an Anjou pear tree, taken in September 1909. The trees in the background are already attacked but will live two or possibly three years yet. The soil is a sandy loam free from alkali and seepage. A hole was dug at the base of the tree and there was no water at a depth of four and a half feet. The photograph shows where a large limb was cut off for examination.

The number of individual trees which have been analyzed is eighty-one, sixty-seven in connection with this bulletin and fourteen in connection with Bulletin 131, and of the eighty-one samples examined I have personally taken fifty-five, possibly more. I have not known the history of the trees in more than a few instances. Orchardists do not, except in rare cases, keep a written record of their doings and I find that any other record is of little value; more satisfying than none, it is true, but not to be depended on. This is in no wise a reflection upon the veracity of orchardists or others, but simply the statement of a very well known fact, i. e., that no one remembers their ordinary, every-day doings for more than a very short time, especially when these doings may be repeated quite frequently but at irregular intervals.

I have arrived at the point where I do not consider statements made pertaining to acts done much prior to the current year, and even then I consider a number of things before I place much value on the statements. This is very unfortunate for it necessitates the rejection of much information that might be very valuable and it increases our difficulties when the help that the information would afford is badly needed. I have been told very many times of trees that had never been sprayed; those trees, however, almost uniformly proved to contain arsenic, copper and lead. I admit that this is not absolutely rigid proof that the trees had been sprayed, but in as much as we have been using preparations of copper and arsenic, lime and arsenic and lead and arsenic with which to spray trees and as these substances eventually find their way to the ground from which the tree draws its nourishment, I submit that one is justified in interpreting the presence of these three substances, or even arsenic and either one of the others, in the woody tissue of the tree, as conclusive that the most probable source of the arsenic and lead or arsenic and copper was spray material which had been applied, rather than any original occurrence of these substances in the soil. This would seem the more probable as spraying of fruit trees has been practiced for not less than twenty-eight years and has been general in our section for about fifteen years. As the trees in question are usually from fourteen to thirty or more years of age, I prefer to accept the testimony of the chemical examination as to whether the tree has been sprayed or not rather than the state-

PLATE IV.

PLATE V.

ment of the present owner, who in many cases knows nothing about the earlier history of the orchard.

In writing of these trees Mr. Whipple made the following statement:

"Two seasons are required for the disease to kill the tree. The first season the trunk is girdled and the foliage drops early. This early ripening of the foliage is often the most prominent symptom and diseased trees can be easily picked out in the early fall. * * * The second season the tree starts in to leaf as the normal tree, generally setting fruit, and dies in midsummer, the fruit and leaves clinging."

This description is entirely correct, but it applies to trees in which the damage has already proceeded so far that we can, with a great degree of certainty predict how soon the tree will die. This too was the phase of the trouble at which we began to study it. We found a zone beginning just below the ground and extending down on to the roots where the bark had been destroyed and the underlying tissues stained brown. The similarity between these conditions and those produced by the arsenite of soda is perfect. The destruction of the tissue is almost as though it had been charred by dilute sulphuric acid but is more complete than would be accompanied by a like coloration if it had been produced by this acid. I have examined a large number of samples of the woody tissues of such trees, and have uniformly found that arsenic is present. The bark has not been used because the arsenical spray material might be mechanically included in it. For this reason the bark has in all cases been carefully removed. Further no dead wood which has been exposed to contact with spray material has been used, so that the results represent what has taken place in the tree itself.

The first samples examined were roots of a pear tree in which the trouble had not proceeded as far as the phase described by Mr. Whipple, but which were not healthy; these roots contained arsenic in large quantitites. Subsequently other pear trees and apple trees were examined with like results till we have examined in all eighty-one trees, apple, pear and peach. The results may be summed up as follows: in every case in which the death of the tree has been cau ed by corrosive arsenical poisoning we find the crown of the tree girdled, the bark below the surface of the ground is usually attached to the tree but is brown or black in color and its texture is wholly destroyed, the woody tissue of the root is colored mostly a deep brown and sometimes its texture too is destroyed. The wood of the lower part of the trunk is usually stained, though it may have no other sign of unhealthiness. This is in no manner similar to a spot of dead wood on the trunk of the tree above the crown caused by freezing or by a mechanical injury. The bark above the line of the ground is intact in most of these cases though there are some instances of trees resembling the one shown in Plate 2, Fig. 1, Bulletin 131, which, however, is not similar to ca es of winter killing with which any of us are familiar. The heart wood even in the limbs and branches is generally, but not always, of a deep brown color with a decided-

ly darker brown margin. This coloring is irregular and does not conform to annual rings. The trees that die of this disease, and I believe that they all die, linger two seasons. Further it is safe to predict that every tree that we now find with a corroded crown and some dead roots will perish within the next few years if left to itself. We have many trees which show no sign of the trouble above ground this year, but which we can safely predict will die within the next two years. The signs above ground are those described by Mr. Whipple. The trees first submitted to analysis were naturally trees that were very sick. But few actually dead trees have been examined. No such sick tree has failed to yield a strong reaction for arsenic. This is most abundant at the crown of the tree, less abundant in the upper portion of the stem and still less so in samples of the branches, but is prsent in all parts of the tree.

I wish to emphasize the fact that we have two phases of the action of arsenic, first the local action of that which collects about the crown of the tree and that which has been taken up from the soil by the feeding roots and in this way passed into the tree with the nutrient solutions. It is evident that if the tree has been sprayed often enough to permit so much arsenic to collect at the base of the tree that it corrodes the crown and roots, the tree will also have gathered arsenic from the soil by means of its feeding roots and no one can say how much of that present in the woody tissue has been taken from the soil and how much has been absorbed through the wounds made by the arsenic on the crown and roots of the tree.

I maintain that we have strong reasons for believing that considerable injury has been done by arsenic absorbed with the nutrient solutions when it produces what I have designated as systemic poisoning. This feature was merely touched upon in Bulletin 131 because as there stated the cases of irritant poisoning are more numerous and, I may add, more evident.

It is evidently out of the question to give the details of sixty or more trees suffering from irritant arsenical poisoning. The observed facts are so uniform that it would only be to restate the same thing as many times as we should describe different trees. In every case we find a zone just below the surface of the ground and involving the large roots in which the bark of the tree is converted into a brown or black mass and the texture destroyed, the woody tissue beneath this is in many cases also destroyed, especially of the roots; in the trunk it is usually partially destroyed and always more or less stained of a brown color. As these trees approach death, usually indicated in the early fall of the year preceding this event, the foliage ripens early. The tree usually blooms profusely the next spring, sets fruit and dies early the next fall, the leaves and fruit often remaining on the tree in some instances until far into the winter or even the ensuing spring. In some cases we have a killing of the bark above ground. This occurs in continuous areas extending up so far as to sometimes involve a portion of a limb. This is shown in Plate 2, Fig. 1, Bulletin 131. The bark is not loosened but is killed, the

juice that exudes is ill smelling and the area is continuous with the corroded crown. The whole section of a root may be involved or only the upper portion of it. There is frequently as sharp a line showing the limits of the attack on the roots as is shown by these patches on the trunk. This illustrated by Plate VI, rep-

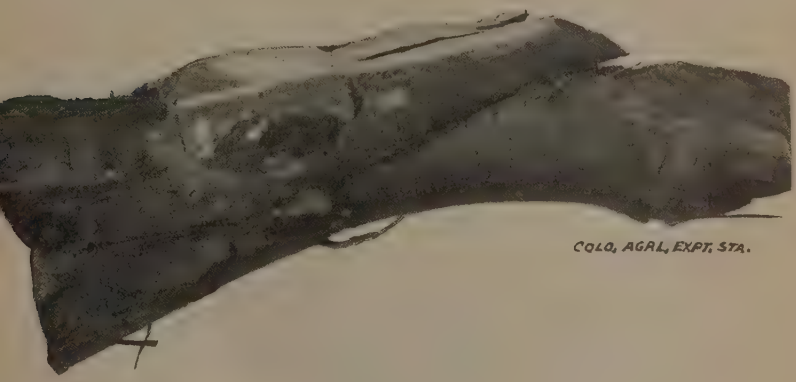

PLATE VI.

resenting the root of an apple tree, the further portion of which was perfectly healthy in appearance, which is also shown in the photograph. It may be of sufficient interest to justify a statement that this root was cut from the tree last May and the tree was practically dead this fall when I last saw it. I have found in such trees from 12.5 parts in the woody tissue to 24.65 parts of arsenic, calculated as arsenic acid, in the disintegrated bark.

Prof. C. S. Crandall, of the University of Illinois, formerly horticulturist of the Colorado Experiment Station, writes me that their chemist, Mr. O. S. Watson, obtained in samples of disintegrated bark which he collected while on a visit to this state 1.8 and 15.8 parts of arsenic per million.

In a sample of disintegrated bark collected from the crown of some pear trees 24.71 parts of arsenic per million, calculated as arsenic acid, were recovered. In the woody tissue of an apple tree root which we know was killed by sodic arsenite, 24.02 parts of arsenic acid were recovered. The inner portion of the bark on the pear tree is for the most part still intact and healthy but the bark is in many places very thin and occasionally we find it eaten entirely through and the underlying sap wood already attacked. The explanation that I offer for this condition is that the spray has been applied heavily enough to run down the trunk and collect around the crown of the tree just as the arsenic collected under the bands described by Dr. Bradbury. It has been soluble enough to saturate the bark to the extent stated, 24.71 parts

per million, and to cause its destruction. This sample of disintegrated bark may have contained some arsenic in the form of the spray originally used. We tried to remove all the soil and adhering spray by sifting, this being the only feasible means of removing them.

The Source of the Arsenic.

We have found arsenic present in every sprayed tree which we have examined. I am fully convinced that every sprayed tree contains arsenic enough to permit of its detection in the woody tissue without the use of any very large amount of the wood. I believe that from two to 4 or at most 6 ounces of wood will suffice for the detection of arsenic. The perplexing feature in this work has not been to detect the presence of arsenic but to arrive at a definite conclusion in regard to its source and action. I have already answered both of these questions.

The presence of arsenic alone is not taken as sufficient proof that the arsenic in the trees came from spray material, though such might be the case, but when arsenic and copper or arsenic and lead or when all three are present at the same time I believe it to be sufficient evidence that the tree has taken it up mostly, if not wholly, from the sprays which have been used. If there is arsenic already in the soil the tree might without doubt obtain a trace from this source. This question, however, will be more fully considered under the subject of systemic poisoning, where it properly belongs.

The Cause of Death.

The crowns of trees growing in our neglected orchards are not corroded although the trees may be in bad condition. The trees that have been killed by nitre have perfect crowns. We have described the condition of the bark on trees showing cases of corrosion. We have shown that arsenic destroys the bark in this manner and have cited at least eight instances in which I have seen the trees. We have shown that this bark contains in the case of the pear trees arsenic equivalent to 24.71 parts of arsenic acid per million of the bark. This observation is supported by the findings of Mr. Watson, who obtained 15.8 parts of arsenic per million, which, assuming that Mr. Watson's figures mean metallic arsenic as I suppose they do, would correspond to 24.22 parts arsenic acid per million. These figures are so high that any other source than the spray material is out of the question; besides we know that the spray material does run down the trunk and into the ground at the crown of the tree. That this is a sufficient amount of arsenic to destroy both bark and woody tissue is plainly shown by the amount of arsenic found in the disintegrated tissues of roots which we know were killed by arsenic, in which was found arsenic corresponding to 24.02 parts arsenic acid per million. The maximum amount of arsenic found in any part of a tree, even when the arsenic was known to have been applied in such quantities as to have killed the tree quick-

ly, corresponded to 34.5 parts of arsenic per million. We have stated that we find this corrosion of the bark in all stages of advancement from a mere film on the bark to a point where it has eaten through the bark and attacked the woody tissue and have found this woody tissue to contain arsenic equivalent to 13.20 parts arsenic acid per million. We have then this series of facts showing the progress of the disease till the girdling is complete, or so large a portion of the crown and roots have been destroyed that the tree dies. The amount of arsenic in the bark and in the tissues in extreme cases is as great as is found in tissues known to have been killed by arsenic but we do not know that the amount found in the destroyed root is not very many times the minimum amount necessary to produce this result. I have no hesitancy in concluding that arsenic applied to trees as arsenical sprays, i. e., as Paris green, as arsenite of lime (lime, sal soda and white arsenic), and as arsenate of lead has produced this trouble.

Arsenic in the Trunk and Limbs.

That I am unable to distinguish, in cases of trees which have died of irritant arsenical poisoning, how the arsenic found in the woody tissue was taken up is evident. The trees described were all in a dying condition but not dead, therefore imbibition after death is out of the question, but whether the arsenic found had been taken up by the wood from the injured crown or had been gathered by the feeding roots from the soil I cannot tell. Since this is simply a matter of fact which cannot be directly observed, I will assume that both methods have played a part. That the roots gather arsenic from the soil will be abundantly proven and further that they may gather enough to injure or even kill the tree. On the other hand it is very probable that arsenic is absorbed directly from the corroded crowns and roots, in which case we would expect the tissues in the neighborhood of the wounds to be richer in arsenic than those parts farther removed. This is, I think as much as can be said in regard to this point.

This is the case in these trees. We have in the woody tissue at the crown of a dying tree as much as 13.20 parts of arsenic, as arsenic acid, whereas in the limbs I have not found more than 3.28 parts per million and this was in a Bartlett pear tree which had been heavily sprayed, having received seven or eight sprayings annually for six years. The crown and roots of this tree were badly corroded and the roots contained 4.821 parts of arsenic acid per million. In a tree near which spray material had been mixed and which had killed the tree I found 8.32 parts per million in the roots and 6.35 parts per million in the limb. The roots and crown of this tree were badly corroded. This sample was taken in the month of March. I do not think that the tree would have put out any leaves if it had been allowed to stand. There is not always so marked a difference between the arsenic content of the crown and the limbs though a difference always exists; in the case of a pear tree, the one shown as a badly affected tree in Plate IV, the root showed 3.505 parts per million while the limbs gave 2.19 and 2.64 parts per million.

It is perhaps proper that I should say a word in regard to these determinations. It is a difficult task to manipulate the destruction of 60 or 70 grams of wood without losing some arsenic, again there is some loss in the Marsh-Berzelius method, again it is impossible to weigh such small quantities except on a button balance, which is not always at hand. In this connection I wish to acknowledge my indebtedness to Wm. Ainsworth & Sons who kindly placed one of their balances at my disposal. This balance was claimed by these makers to be accurate to 0.005 milligrams, and the balances are as represented. The weighings are accurate but the difficulties in the recovery of the arsenic will not justify us in claiming the highest degree of accuracy for them. One thing however can be said, i. e., they are all too low, and this without an exception. This I think will be readily acceded by persons competent to judge. The pages of a bulletin are not, in my opinion, the place to discuss analytical methods, therefore this subject will not be mentioned further than to reiterate the statement made in Bulletin 131: "That the reader is assured that the arsenic reported was not contained in any or all of the reagents used. The care taken was in all ways as circumspect, so far as the analytical work was concerned, as though human viscera were in my hands." Trouble was had in obtaining zinc so nearly free from arsenic that one could use it without misgivings.

The Part Played By Alkalis.

I was very explicit in my statements regarding this subject in Bulletin 131. I see no reason to change any statement made therein, namely that lead arsenate yields arsenic quite readily to dilute solutions of sodic sulphate or sodic chlorid and these are our common alkali salts. The other salts always understood, when we use this term, are the sulphates of lime and magnesia. Distilled water dissolved arsenic acid from the arsenate of lead which we used though it, the lead salt, had been previously washed, but water to which sodic sulfate or sodic chlorid, ordinary salt, has been applied will dissolve it more readily. This is true of the neutral lead arsenate and probably in a higher degree of the acid arsenate. Arsenite of lime (lime, sal soda and arsenic) is quite soluble in water but more readily so in water to which sodic chlorid or Glauber's salt has been added. I have, however, met with soils in which there is so good as no alkali and yet a very considerable amount of arsenic can be dissolved out of this soil by distilled water. I have even obtained soils from states in which alkali is not supposed to exist and these soils, too, contain arsenic which is soluble in distilled water and the quantity is so significant that it raises a doubt in my mind as to how big a part our alkalis actually play in the matter. It is evident that they may take some part in bringing the arsenic into solution in water but they are certainly not the primary cause of its solubility. As elsewhere stated, all of the arsenical compounds used as spray materials, Paris green, arsenite of lime and lead arsenate, are perceptibly soluble in water and consequently any soil containing these salts in sufficient quantities ought to yield arsenic to pure water, as

they actually do. The alkalis in our soils certainly tend to increase this solubility, but as stated, we find so much water soluble arsenic in soils free from alkali that I am now very much inclined to attribute a rather small part to them, and to take the statement first made by Prof. Whipple, that "soil conditions seem to have no relation to the disease" in the broadest possible sense. I, however, am not willing to say that the alkalis have no influence but simply that I am convinced that they have much less influence on the question than I formerly thought. This view is not only forced upon me by the fact that soils free from alkali contain water soluble arsenic, but also by the fact that I have found so many trees injured by arsenic and yet the soil in which they had grown could not be called an alkali soil without actual disregard of facts.

In order to test this point further and at the same time to determine the difference in the deportment of the orthoarsenate of lead, $Pb_3(AsO_4)_2$ and the acid arsenate, $PbHAsO_4$ with dilute solutions of the ordinary "alkali" salts, i. e., sodic sulfate and chlorid, six series of experiments were made which extend those described in Bulletin 131 in that sodic carbonate is included in the solutions and further we have endeavored to determine the arsenic acid that went into solution.

The first solvent considered is sodic sulfate, because this is our common alkali. Three strengthes were used: one, two and three grams per litre. The strongest of these is weaker than many of our soil waters, but is probably as strong as the soil waters in the majority of our orchards. It is very certain that quite a number of orchards can be found in which the soil itself will contain a larger amount of sodic sulfate than 0.1 per cent, or one part per thousand; on the other hand there are a great many that do not contain this much. This statement is made because there are many places where we sometimes meet with saturated solutions of this salt and this condition is supposed to apply to all, or to a very large portion, of the orchard land which is too broad an inference. One and one-quarter gram of the lead arsenate was added for each litre of the solution and the whole shaken frequently.

The solubility of the acid lead arsenate in water was not determined but it has been previously stated that distilled water dissolves about 0.3 per cent. arsenic acid out of the triplumbic or neutral arsenate. According to this each litre of water would dissolve 3.7 milligrams of arsenic out of the 1.25 grams of ordinary arsenate of lead. Portions of the solution were taken at the end of 24 and 72 hours. We had some trouble to obtain perfectly clear solutions. The difference in the amounts of arsenic dissolved being quite small the range being from 3.9 to 7.2 milligrams per litre. I give the average of eight determinations made with the sodic sulfate which is 5.6 milligrams of arsenic acid per litre for the triplumbic arsenate. This includes the thre strengths used, 1, 2, and 3 grams per litre, or parts per thousand. The acid arsenate, $PbHAsO_4$, gave higher results from 3.8 milligrams per litre in 24 hours for the solution

containing one gram sodic sulfate to 10.5 milligrams in 72 hours for the solution containing three grams sodic sulfate per litre. The average for the eight determinations made is 6.4 milligrams arsenic acid per litre.

The acid arsenate is more readily attacked even by these weak solutions than the ordinary arsenate of lead; but both yield significant quantities.

Previous experiments had inidcated that sodic chlorid (common salt) is much more vigorous in its action on lead arsenate than the sodic sulfate or Glauber's salt. Sodic chlorid is not present in large quantities in our soils and for this reason I used only one-half as much sodic chlorid as sodic sulfate, i. e., one-half, one, and one and a half grams to the litre. As the amounts dissolved and the differences are greater I will state them in tabular form. Ordinary lead arsenate is $Pb_3(AsO_4)_2$, the acid arsenate is $PbHAsO_4$. The results are stated in milligrams of arsenic acid.

		Ordinary	*Acid*
½ gram NaCl per litre	24 hrs.	31.2	68.6
	72 hrs.	——	72.4
1 gram NaCl per litre	24 hrs.	32.3	74.6
	72 hrs.	48.8	95.1
1½ gram NaCl per litre	24 hrs.	36.9	108.4
	72 hrs	47.6	113.4

Sodic carbonate (sal soda) was used in solutions one half as strong as the sodic chlorid, because it is present in our soils in quite small quantities.

		Ordinary	*Acid*
¼ gram Na_2CO_3 per litre	24 hrs.	48.1	114.5
	72 hrs.	56.7	131.1
½ gram Na_2CO_3 per litre	24 hrs.	44.2	157.6
	72 hrs.	56.7	160.9
1 gram Na_2CO_3 per litre	24 hrs.	54.4	157.1
	72 hrs.	55.0	158.7

The ordinary lead arsenate, $Pb_3(AsO_4)_2$, is attacked a little more freely by water containing only a comparitively small quantity of sodic sulfate than by pure water and the amount dissolved increased slightly when we increased the amount of sulfate from one and two to three parts per thousand. Even small amounts of soda chlorid and carbonate decompose the arsenate to a marked extent. The acid arsenate, with thirty per cent or more of arsenic acid, is attacked more vigorously by each of these substances, sodic sulfate, sodic chlorid and sodic carbonate, than the ordinary arsenate with about 26 per cent of arsenic acid. This difference is quite important as the acid arsenate is coming into more general use.

The Part Played By Water.

I know that Prof. Whipple had this condition in mind as much as any other when he made the statement that soil conditions seem to have no relation to the disease and I also had it in mind when I corroborated his statement. This trouble appears on high as well as low ground, on sandy soil as well as in heavy soil. The pear tree shown in Plate IV stands in a light sandy loam with a decidedly sandy subsoil changing to gravel at the depth of four feet. I sunk a hole a little deeper than this at a season when the whole country was being irrigated, namely, at the time of the autumn irrigation and at a depth of a little over four feet this soil was almost dry. I have seen trees drowned but the water in these cases had risen quite to the surface and had remained there for a long time, how long I do not know. These trees do not belong to this class.

In this connection I will again state that trees killed by nitre poisoning present nothing in common with those killed by irritant arsenical poisoning. Trees killed by nitre generally have perfectly healthy crowns and roots. Most of the cases that I have examined have had perfect crowns, in fact I think that they always have unless there is some complication of trouble, as irritant arsenical and nitre poisoning, in which case the tree might die of nitre poisoning though it had a corroded crown.

There is an orchard which I am convinced has suffered several years from a rising water plane and an excessive quantity of nitre. This orchard is drained by a 7x6 inch box drain which discharges a large amount of water but it is not sufficient. The water discharged from this drain carries 637.2 grains of mineral matter in each imperial gallon of which 14.5 grains was sodic nitrate or its equivalent. The crowns of these trees and the roots at the crown are apparently perfect but the trees are in bad condition and many of them have been removed. The distal ends of the roots are killed, rotted off. This I believe, has been done by the high water plane. These trees present an entirely different case from trees killed by irritant arsenical poisoning.

Trees That Have Not Been Sprayed.

I introduce this subject for the simple reason that through this claim for certain trees I found some very instructive and interesting cases. It is a very common thing for persons to state that "those trees have never been sprayed." I have been deceived by this statement so often that I now pay no attention to it at all. I have examined too many trees that "have never been sprayed" and found arsenic, copper and lead present which I consider as establishing a strong presumption that the tree has been sprayed. In this instance, however, I know the owner personally and he was so positive and his statement was corroborated by at least one other member of the family, that when I saw the trees which I thought were surely not sprayed I did not know what to think. I at once saw that I had to examine at least two of the trees, for if these trees had not been injured by

arsenic then I had at last found an instance of apple trees with corroded crowns and all the other conditions which I had been attributing to the irritant action of arsenic which were not due to this cause. I took samples of the corroded roots of two trees and found arsenic without any trouble. I knew that my friends had not tried to deceive me and was certain that an explanation was to be had. I suggested to them that potatoes might have been grown between these trees and had been sprayed with Paris green or possibly lead arsenate. This proved to be the case, and while the trees had not been sprayed as apple trees, they had been sprayed with the potatoes. At this time it is impossible to learn whether these trees had ever had the poison applied directly to the body of the tree or not. A few points, however, are established: that the crowns of these trees were girdled, the roots were corroded, arsenic was present in the woody tissues of the trees, the trees have since died. They were never directly sprayed as apple trees but potatoes were grown between these trees and were sprayed with Paris green in the earlier years of the orchard and later with disparine, a trade name for arsenate of lead. I will here mention another case, a little different it is true, but somewhat to the point suggested by the preceding instance. Two young trees were set in the places of two dead trees and stood three years and died. Prof. Whipple was asked to examine the trees, and suspected that they had been killed by arsenic, but these trees had never been sprayed. I visited Grand Junction soon after that and he asked that I go and see these trees, for if the facts were wholly as stated to him I might have to make some exceptions to my general statements. I went and found that the owner had pulled them up and buried them. We dug them up, washed them off and examined them. I, too, felt certain that they had been killed by arsenic. The owner at first insisted that they had never been sprayed, which in one sense was true, but he admitted that the boys had turned the spray on them as they drove past them while spraying the orchard. I asked him for the history of the trees and found that he had a young orchard three years old and these two trees were from the same nursery lot which he had planted in the young orchard. I asked him how many trees had died and he said none but the two trees that he had set in the places of two old sprayed trees and which they had just sprinkled as they drove by with the spray tank. The crowns and roots were corroded and arsenic was present in the woody tissues of the one that I examined. I give the cases of these four trees as suggesting, but nothing more than suggesting, the answer to a question which has frequently been asked: Is it safe to plant young trees in an old, long sprayed orchard? I have uniformly confessed my inability to give an answer to this question. These cases certainly suggest the possibility of danger, especially if the soil filled in around the crown should chance to be rich in arsenic.

This and other serious questions are by no means new to many of our orchardists. One of them rather anxiously asked me in the early spring of 1900, "What are our old orchard lands worth?" This, too, is

a suggestive question which I have not ventured to answer.

An elm tree first called to my attention by Mr. H. A. Richardson, Horticultural Inspector for Delta County, presents a most interesting case. Some may feel that the trees previously mentioned had in effect been sprayed; at least the cases need explanation in order that the claim that they had never been sprayed may be understood. There is no doubt but that the first two trees mentioned had not been sprayed, but no one can at this time so much as surmise what may have happened whereby the arsenic may have been applied around the base of the tree. With this elm tree, whose condition in October, 1909, is shown in Plate V the case is different. The bushes in the left hand side of the picture are lilacs; in the background are apple trees of different ages. That portion of the background occupied by young apple trees was formerly a pear orchard. In the spring of 1909 this tree was in such a condition that its owner became anxious about it, especially so as it is a tree the care of which has been a pleasure and whose growth has delighted the owner because it has attached to it memories and a sentiment which none but the owner may share. The conditions found are fairly indicated by the limb on the right; the leaves were dying and this side of the tree was in evident distress; the condition was so bad that the people were glad to have the limb taken for examination. The wound made in removing the limb bled freely and smelled very offensive. The interior portion of the limb was very dark and examination showed the presence of a considerable quantity of arsenic. I have endeavored to find something in the history of this tree which would explain this but I have found nothing.

A roadway passes in front of the tree and on this side of the road is the kitchen garden. The tree has never been sprayed. They did mix a little spray material, lime, sal soda and arsenic, just beyond the lilac bushes once, now seven or more years ago. I have been unable to find any other specific cause for the trouble. This case has been so interesting to me that I have made four visits to the place. The condition of the tree grew steadily worse throughout the past season. Beginning at the point where the limb was cut off one can follow an injured strip running somewhat spirally down the trunk. It is lost at the crown of the tree. I give this fact because I followed this injured strip expecting to find it leading to an injured root which I might follow to the place where they had mixed the arsenite of lime but I was disappointed. So with the aid of Mr. Herrick, our present Field Horticulturist in this section, I traced out the roots of this tree to see if we could find any of them either dead or showing injury. We traced five different roots for a distance varying from twenty to twenty-five feet and found no external injury to the roots except at one place and this I am sure had been done by the ploughshare. We, however, found some roots which were not healthy as they had spots on them and on stripping off the bark we found the inner side of the bark and the tissues of the root colored brown or brownish

and livid. The soil at a distance of twenty-five feet from the base of the tree was well filled with fibrous roots of the elm tree. The soil showed by qualitative test that it contained an abundance of arsenic. There remained but one thing for me to do and that was to take more samples. I accordingly cut off one of the roots at a point six feet from the base of the tree and took a section of the root three feet long for a sample. I also took a small limb from the healthy appearing side of the tree. These samples showed the presence of arsenic in considerable quantities. We have in this case a tree which has never had any arsenic applied to it directly. It is not in any way indicated that the tree was injured by the lime arsenite which was mixed at some distance from the tree, but I do not say that it was not. I say only that I failed to find any proof that it was injured, and my judgment is that it is very doubtful whether that operation performed seven or nine years ago had anything to do with the present troubles, except as it has contributed to the general conditions. The root taken started out between the two little bushes near the tree, then turned to the right and ran straight back into the orchard. We find, that some of the roots show a diseased condition quite similar to conditions found occasionally on the trunks of the trees. We find that the woody tissue of the root contains arsenic and also that of the limb taken from the apparently healthy side of the tree. The limb which has been removed was dying; one of the limbs remaining on the right side of the tree is dead. It presented all the signs which accompany the death of trees killed by arsenic and arsenic is present. I have no hesitancy in saying that arsenic is the cause of the trouble and the death of the limb. This tree which has really never been sprayed, and which appears to have escaped accidental poisoning but whose roots were feeding in a soil rich in arsenic, is dying of arsenical poisoning.

The soil in this case is a red mesa soil somewhat clayey and at the same time calcareous, I would say marly, it effervesces freely with acids. I do not know how far it is to water, but judging from the line at which the seepage water breaks out below the edge of the mesa, twenty-five feet is a conservative depth to assume for the water plane.

The ash of the smaller limb which the plate shows as having been cut off shows the presence of copper, but the presence of lead is doubtful. A porcelean lamp was used in incinerating the wood; so that there is no question but that the copper was contained in the wood; besides the quantity present is too big to have come from the flame of a Bunsen burner in the ordinary course of work.

The virgin soil from this mesa was tested for copper, lead and arsenic. One hundred grams of soil failed to give a trace of lead. By careful manipulation we were able to establish the presence of a minute trace of copper, but there is a more decided quantity of arsenic present. The orchard soil is decidedly rich in copper and arsenic. It was not tested for lead and needed not to have been for arsenic, for we know that the arsenate of lead has been put on the soil in spraying the trees. The quantity of arsenic and copper present is much greater than that in the virgin soil and the presence of the two,

arsenic and copper, is conclusive proof that this tree has obtained the arsenic which we find in its roots and branches from the spray material applied to the adjacent pear and apple trees, for the tree itself has never been sprayed. In this tree we have no corroded crown, but there is an injured strip running obliquely up the trunk. I could not trace it below the surface of the ground. While some of the roots show signs of disease none of them are corroded. One side of the tree is already dead and the trouble is involving more and more of the tree; arsenic and copper are present in the woody tissues of the limbs. The root was tested for arsenic only. There seems to me no other conclusion to draw from these facts but that the tree has gathered these poisons from the orchard soil.

Lead and Copper in the Trees.

The question whether these metals are playing any part in the troubles which we are discussing or not is certainly germane, but while I am ready to believe that they may have some influence the action of the arsenic seems so clearly to be able to account for all that we have found, that it seems needless to attempt to discuss either lead or copper though we know that the latter can and has injured trees when used in too large quantities.

I have examined a large number of trees for the presence of lead and have always found it. Lead has been determined in but one sample in which 0.003% metallic lead was found. This is practically all that we have done with the lead and copper, i. e., we have examined the woody tissues for them, because I consider their presence as establishing the source of the arsenic with a fair degree of certainty and not because I wished to consider the question of their poisonous character.

The Effect of Lime.

This question is involved in more obscurity than any other that has been met with up to this time. I know of several orchards in which the trees are small for their age and do not show the thriftiness that the care they have received would justify one in expecting. Four of the orchards that I have in mind receive excellent care, but many of the trees are not healthy. There is some irritant arsenical poisoning present but these cases are not numerous and it has nothing to do with the condition here discussed. The one feature that I wish to present in this paragraph is that of bleeding. Namely, the wounds made in trimming last season will bleed badly this season. They sometimes do not bleed the first season but bleed badly the second. In some of these orchards the bark splits and bleeding ensues. The splitting of the bark may take place on the limbs or on the trunk. The bleeding is almost always profuse. This bleeding is so far as I can recall at this time confined to land that is very marly or underlaid by a stratum of marl. Sometimes this stratum is quite thick, two feet or more, at others it may not be more than a few inches in thickness.

The bleeding is sometimes quite profuse, so much so that the outflowing sap may encrust the trunk with a yellowish white deposit for several inches below the split, or if on a limb for a foot or more. I have seen it drip and build little stalactites three inches or more in length and cover the limb with a deposit an eighth of an inch thick. This material seems to be gathered from the soil and is the sap or solution sent up into the tree by the roots and is probably not produced within the limbs or tissues of the tree. This of course cannot be observed, but the following example will make my meaning plain. A limb of a Jonathan apple tree was cut off on the eighth of April. It was cut off close to the trunk of the tree, not more than two feet from the ground. The tree was not healthy, but no more unhealthy than the average tree in the orchard. On the twelfth of May I found that this wound was bleeding and was already covered with the deposit described above. This sap was then exuding through the medulla, as was easily observable. No bleeding could be observed from the sap wood. This bleeding is very marked in some orchards and practically absent in many. The deposit is the same in appearance wherever I have seen it. The soil of these orchards is underlaid by marl and the soil itself is marly. I think that the great majority of our soils carry more than five per cent. of carbonate of lime. This deposit contains 25.00 per cent. of calcic oxid and 49.0 parts per million of arsenic, calculated as arsenic acid. The cracking open of the bark and the bleeding is shown in Plate 5, p. 16 of Bulletin 131, and as it is still representative we will use it again as Plates VII and VIII.

I know nothing about the contents of total solids in normal apple tree sap, but this sap is evidently very rich in total solids which as represented by these deposits are soluble in cold and hot water, but difficultly soluble in alcohol. If to the aqueous solution some alcohol, not enough to precipitate it, be added, fine acicular crystals deposit on standing. Calcium is essentially the only inorganic base present but is accompanied by a small amount of magnesia and the alkalis potassium and sodium.

Lime was not mentioned in the preceding section because it is always present to some extent in the ash of plants and in all soils, and the amount of lime added with the arsenite of lime is extremely small when compared with the lime in our soils for which an estimate of 65 tons per acre foot is very moderate. The soil of one of the orchards referred to carries in the surface foot calcic carbonate equivalent to 224 tons of burnt lime, while the subsoil is still more limey. The supply of lime is excessive, the ability of plant roots to dissolve calcic carbonate is well known, so the appearance of lime in these deposits is no matter for surprise, but the appearance of so large an amount of arsenic, 49 parts per million, is sufficient to raise a question in regard to its source and its relation to the lime.

Some plants are calcifugous but the apple does not seem to belong to this class, for it does well and lives long in limestone soils, not only in other states but also in Colorado. I know of a small or-

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PLATE VII. (upper), PLATE VIII. (lower)

chard set in a soil so thin that it scarcely covers the underlying calcareous shale and I could find none of this bleeding in these trees. The orchard is young and fairly thrifty. It is further true that this bleeding is not universal throughout the fruit growing sections of the state while the presence of lime in relatively large quantities is certainly the rule with only a few exceptions.

In Bulletin 131 I stated that the question is: Are these trees suffering from systemic arsenical poisoning, lime poisoning, or both? Again I have repeatedly expressed my opinion that it is doubtful whether we can distinguish the part which each plays in the case. There can be no doubt, and there is no doubt in the minds of thoughtful men conversant with the facts, but that something is the matter with these orchards. This does not mean that the trees are dead or that the orchards may not continue to give very handsome returns for years to come, but simply that the trees are not healthy and that the bad condition of some trees is possibly due to this cause. Arsenite of lime was at one time our generally used spray material and it is possible that soil conditions may have been such that this in some cases caused the injury.

The lime and arsenic may have been taken up together, that is, in combination, or taken up at the same time but not in combination and we are not able to distinguish their separate action. I would make no mention of this matter if I did not believe it to be of such importance as to demand mention.

I have studied these marly soils to see if I could find anything indicative of an explanation for this condition. Orchards do quite well on some of these lands, especially if the surface soil is twenty inches or more deep and not too rich in lime. The following analysis will give an idea of their composition:

ANALYSIS OF MARLY SOIL.

Insoluble	48.589
Soluble Silica	17.071
Chlorin	0.008
Phosphoric Acid	0.036
Carbonic Acid	8.532
Lime	11.695
Magnesia	1.674
Sodic oxid	0.374
Potassic oxid	0.589
Ferric oxid	4.890
Aluminic oxid	4.554
Manganic oxide (br)	0.179
Ignition (loss)	(1.776)
Sum	100.002
O Equiv to Cl	.002
Total	100.000
Total Nitrogen	0.386

According to this analysis, the amount of phosphoric acid present is scarcely good but the supply of other plant food is very fair That this soil contains arsenic is assumed as the orchard has been sprayed for years. The carbonic acid, CO_2, present corresponds to about 19.38 per cent. of carbonate of lime. The preceding is a surface soil.

One of these marly subsoils had the following composition:

ANALYSIS OF MARLY SUBSOIL.

Insoluble	55.683
Soluble Silica	2.866
Chlorin	trace
Sulfuric acid	trace
Carbonic acid	12.444
Sodic oxid	0.390
Potassic oxid	0.360
Calcic oxid	16.538
Magnesic oxid	2.438
Ferric oxid	3.428
Aluminic oxid	1.326
Manganic oxid (br)	0.260
	100.033

We have here about 28.28 per cent. of carbonate of lime or marl. This subsoil was taken at a depth of twenty-three inches, and though representing the subsoil of a sprayed orchard I deemed it of sufficient interest to determine the arsenic that it might contain and found 15.33 parts arsenic, calculated as arsenic acid, per million. I scarcely think that the spray applied to the trees would find its way down into this marl. This orchard had been given surface cultivation only, still I acknowledge the question as an open one whether this arsenic is an original constitutent of the marl or an adventitious one arising from the practice of spraying. Personally I believe that the marl itself has always contained the arsenic.

I will give an analysis of a marl from still another place. This sample was not taken in the orchard itself but from an adjoining piece of land belonging to the same owner as the orchard. I will state that this orchard showed a pronounced case of rosette.

ANALYSIS OF A MARL.

Insoluble	24.098
Soluble Silica	8.269
Sulfuric acid	0.350
Carbonic acid	27.115
Calcic oxid	34.525
Magnesic oxid	2.942
Iron and Aluminic oxid	1.960
Manganic oxid (br)	0.180
	99.439

This analysis indicates the presence of about 61.5 per cent. of carbonates, almost wholly lime carbonate and a quantity of decomposable silicates. The most interesting point, however, is that this marl contained 5.21 parts of arsenic, calculated as arsenic acid, per million. These marls open the question of the presence of arsenic in our marly virgin soils. I have stated repeatedly that the greater part of the soils to be considered in this connection are to be considered as marly. I have therefore tested some of our virgin soils from land not yet brought under irrigation. The two already given cannot be considered as virgin soils, i. e., the subsoil twenty-three inches below the surface with 15.33 and a marl with 5.212 parts of arsenic acid per million. I have determined the arsenic in five virgin soils concerning which there can be no mistake about their having never received an application of arsenic, at least not the whole five, which were taken from localities about sixty miles apart. I found in these soils the following quantities of arsenic per million parts of the soil: 2.8, 3.8, 4.2, 4.5, and 4.7 parts. I have further examined six other samples of soils concerning which some doubt might be entertained but I am fully satisfied that two of them have never been sprayed or received the application of any arsenic whatsoever and still it was present.

In connection with this bleeding I have been confronted with the assertion that some of it has been observed in the case of some trees which had never been sprayed. I have not seen such myself but if the observation be correct, it would point rather directly to the arsenical lime, whether native or artificially added, as the cause of this particular trouble, and I believe this to be the case. Those orchards in which I have found this trouble the worst are on such marly soil as I have described, and so far as I know their history, were treated very liberally with arsenite of lime when this preparation of arsenic was exclusively used as a spray material. The samples of virgin soil in which the arsenic is present and cannot be attributed to any known source contain a comparatively small amount of arsenic compared with the orchard soils, in round numbers one tenth as much. This statement does not consider the marly subsoil containing 15 parts arsenic acid per million because some of this arsenic may have been derived from the arsenical spray put on the orchard. No one has, so far as I know, attempted to determine to what depth these sprays may affect the arsenical content of the soil, but as they are decidedly soluble in water it is easy to conceive that the depth to which the arsenic may penetrate is greater than we might think. The sample of soil taken to the depth of one foot and showing 138 parts arsenic acid per million is also excluded from the above statement that the orchard soils contain ten times as much arsenic as the virgin marly soils. As our transplanted apple trees are shallow rooted, seldom feeding to a greater depth than two and one-half feet, it seems probable that they gather their food from the soil proper. I do not think that the marls underlying these lands enter into the question to a great extent, besides

only one of them has been found to contain more than five parts arsenic acid per million.

In regard to the solubility of the arsenic in the orchard soils, I have shown that as much as 1.26 and 1.34 parts of arsenic acid per million of soil is soluble in water. The virgin soils on the other hand yield only traces or none. In this connection it is to be remembered that the roots of the trees may be much more effective in bringing the arsenic into solution than distilled water.

This bleeding takes place from cracks in the bark and also from old wounds made in trimming and is especially noticeable in wounds already one year old. I have watched this taking place, when the juices were issuing through the medulla while no other portion of the section seemed to be taking any part in the process. It is common to find this section of a wound surrounded by this deposit which is rich in lime and arsenic. The medullary tract seems to be the easiest channel for these juices to traverse, which may itself be an indication of a diseased condition. Prof. Longyear has suggested that the ducts whose function it is to conduct the sap of the tree upward, may be so clogged and the resistance offered to the upward diffusion of the sap so great, that it follows this unusual course. The Professor kindly consented to examine sections of affected trees and gives me the following statement of his findings:

"Three lengths of affected branches, two inches in diameter, in which an outer layer about one-fourth of an inch thick of healthy sapwood remained, were brought to me in a fresh condition in February, 1910.

"Transverse sections from different portions of these branches under the microscope showed the ducts in the uncolored sapwood free from obstruction and the cells of the medullary rays stored with starch. In the most highly colored zone, just between the healthy and the affected wood, the ducts were found to be filled with a yellowish or brownish gummy substance, insoluble in cold water and dilute solution of caustic potash. Toward the center of the branch this gummy material diminished in quantity quite rapidly but was not entirely lacking. In the colored area the medullary ray cells still contained in some instances a little starch but in most cases they were partly filled with brownish granules and globules of substances remaining or arising from the disorganization of the cell contents. It is evidently from these sells that the gummy matter has found its way into the ducts. This is shown by the fact that this material appears in a duct first on the side next to the nearest medullary ray cells."

In regard to the varieties affected I have seen this bleeding in the Jonathan more often than in any other, but it is not confined to this variety. I have also seen it in the Missouri Pippin, in the Spitzenberg and other varieties.

The facts seem to me to point to the action of arsenic in conjunction with lime rather than to the action of either alone as the cause of this trouble.

Systemic Arsenical Poisoning.

What I have said concerning the action of arsenic and lime might properly, perhaps, have been put under this head, but I have chosen to treat it by itself because it is so pronounced a feature that it is not possible to overlook it and it will be more easily recognized by those familiar with it than if it were included under this caption.

While there is no single feature in the cases of the trees remaining to be described which may be taken, as the destroyed bark of the crowns and roots in the first, or the deposition of an incrustation on the surface of the wounds or on the bark in the second case, as guiding features, we have some which force themselves on our attention one is a reddish yellow color of the bark, especially of the limbs, another is the lack of thriftiness. The former is not, in my opinion specifically diagnostic of arsenical poisoning but rather of malnutrition, itself a result possibly of the arsenic.

I have seen this color in an orchard which I am convinced is suffering more from other causes than from arsenic, though it may have contributed some in bringing about the bad condition of the orchard. As I shall not refer to this orchard again, I may describe briefly some of its more marked features. This orchard, in the spring of the year, is a very marked feature of that section of the country because of its abnormal color. There are but few or no signs of corrosion. A large number of these trees were pulled up in the late winter and spring of 1909. The ends of one half of the roots this is the estimate of the man who pulled them up and not mine, were found to be rotted off. Some of the remaining trees were pulled up and a few of the roots were found to be in this condition. It is my opinion that the color of this orchard is mostly due to starvation but this forms a part of another study, and is mentioned to dissipate any idea that some might get that this reddish color is diagnostic of arsenical poisoning. This color is not due to sunburning. I have considered this, but there are some facts very hard to explain on this theory, for instance this color is only a little more intense on the south side of the limb than on the north side and all of the trees of an orchard may show this color.

Almost any tree in some of these orchards might be used as an example to illustrate and introduce the discussion of systemic arsenical poisoning.

I have stated that the subject of the action of lime and arsenic might have been included under this caption and the first example is a Jonathan; the tree is small for its age, about 14 years old, the bark is somewhat yellowish and it represents a case of moderate bleeding. The deposit formed is rich in arsenic. I cut off a limb of the tree; the interior portion of it was strongly discolored, the discoloration was not confined to the annual rings. An examination of this wood showed the presence of arsenic. Both of the preceding tests were repeated with a confirmation of the results. The crown of this tree is not corroded. We evidently have in this case

an instance in which both the lime and arsenic are present and it is difficult to judge whether the arsenic, independent of the lime, is the cause of the bad condition of the tree.

The next case is that of a Spitzenberg. The tree was small for its age, crown was good, bark very yellow, foliage during the preceding season small, scanty and of a bad color throughout the season and ripened too early. This tree was dug up in the spring of 1909 because of its bad condition. The wood from the center of the tree outward for nearly an inch was brown but not deeply colored as the Johathan just described. This tree showed no bleeding. A limb of this tree was taken for examination and the woody tissue showed as strong a mirror as some of the trees which had corroded crowns. The mirror was weighed and corresponded to 2.19 parts arsenic acid per million of wood.

The soil sampled to the depth of one foot at the point where the tree had been pulled up showed the presence of 138 parts of arsenic acid per million of soil. This soil also showed that there was 1.345 parts of arsenic acid per million of soil soluble in cold water.

In investigating further it has been shown that the leaves of apple trees which had, during previous years, been regularly sprayed from two to four times, but had not been sprayed this year, contained arsenic equivalent to 2.628 parts of arsenic acid per million parts of the dried leaves.

I have examined a number of samples of apples and pears from Colorado and other states, namely, from California, Michigan, New York, Pennsylvania, Ohio and Illinois, and found them all to contain arsenic. Some of these samples were bought in market, but for others I am indebted to the officers of the respective Experiment Stations and it is a pleasure to acknowledge my obligations to them. I may state in this connection that the above fact is not the only one indicating that other states where spraying has been diligently practiced are suffering as we are but not to the same extent.

I have stated above that the fruit of seven states, as found upon the market or furnished me by their Experiment Stations, contain arsenic. I have weighed and calculated the arsenic as arsenic acid in a few cases, and the results are per million parts of fresh apples as follows: 0.51, 0.68, 2.30, 0.52, of pears 0.52. The total number of samples of fruit examined is twelve. These were either known to have been grown on sprayed trees or supposed to have been. It is possible that the sample showing 2.3 parts per million ought to be left out of consideration but I know of no reason why it should be except that it is very much higher than the other results. These samples were washed and pared and the calyx cup and ovary cut out; no greater care than this could be exercised to avoid getting any spray material into the sample. I further met this possible error by obtaining fruit from trees not sprayed this year and I found that this, too, contained arsenic.

As the ability of the tree to take up arsenic from the soil is an important factor in systemic poisoning, I have endeavored to

ascertain whether trees which had never been sprayed take up arsenic. We have presented several cases in which the application of sodic arsenite to the soil, within the feeding area of the roots, was followed by the almost immediate taking up of the arsenic and death of a portion or the whole of the tree. I have mentioned in all eight instances of this sort, one instance of an apple tree within a few feet of which the spray tank containing arsenate of lead was emptied followed by the death of one limb of the tree, and further the case of the elm tree has been given somewhat fully. It would seem that these cases would suffice to prove that trees will take up enough arsenic from the soil to injure them, even when the arsenic has been applied in a difficultly soluble form, as in the cases of one apple tree and that of the elm tree. To add to the force of these samples, I have examined peach trees which had not been sprayed but which were growing in land already rich in arsenic and these too contained arsenic though two of them were only five years old. The elm tree and the peach trees could not have gotten the arsenic except through the activity of the roots. If further proof is needed the presence of arsenic in the juices forced out of a fresh wound and in the leaves and fruit which had never received any spraying certainly indicate that the arsenic is carried with the sap of the tree. It can certainly make no difference whether the arsenic is originally in the soil or has been added, but the proofs are not wanting that this arsenic comes from the spray materials put upon the soil for it is associated in many cases with both lead and copper, as much as 0.003 per cent of lead having been found in one sample. These facts establish this, i. e., that the trees do take up arsenic from the soil together with lead and copper.

One of the effects of the arsenic on these injured or partially killed trees is to stunt them. This is especially noticeable in those parts which we know to have been affected by sodic arsenite.

Other causes for the unhealthy condition of these trees, their small size, the unnatural color of their bark, the early yellowing of the leaves, the small size and exceedingly high color of the fruit, have suggested themselves. Among these are insect injuries, atmospheric conditions, soils, etc.

We can, I think, dismiss insect injuries, these having been carefully watched for and guarded against, and also atmospheric agencies, including smoke, electricity, etc., and turn our attention to the soil conditions. The average depth of the soil is stated to be from three to three and one-half feet. I think that this is too high for the whole apple orchard, but if the soil is two and one-half feet deep it is quite sufficient for the sustenance of healthy apple trees. There is, however, scarcely a healthy apple tree in the orchard or at most only a few of them.

Whatever our views may be regarding the injurious properties of alkalis we cannot satisfactorily explain the trouble on the theory that they are injuring the trees, for the total water soluble portion of the soil amounts only to 0.22 of one per cent, whereas we have healthy orchards in soil containing a much larger quantity of alkalis than this.

There can be no question of seepage for this is as high as any land in the neighborhood and there is no source from which seepage can come.

There can be no question of ground water for it is necessary to sink wells to a depth of seventy-five feet to obtain water. On the other hand there can be no question regarding the supply of good irrigation water for this is abundant.

This orchard has received intelligent care, neither has labor nor money been spared to make it a good orchard.

These considerations eliminate the questions of neglect, seepage, alkali, the lack of water or the irrational use of it as agencies in producing the present conditions, but they do not eliminate the question of an unfertile soil. If it were not that I know that some very competent persons consider this point seriously as the possible cause in this case I would not discuss it.

Personally I have but little confidence in the results of a soil analysis as criteria whereby to judge of the fertility of our soils. An analysis may have some value, especially if it shows an absolute deficiency in some of those elements which we have found to be essential to the development of plants.

The following analysis, made to answer, if possible, the question in regard to the lack of plant food in this soil, shows its composition:

ANALYSIS OF AN ORCHARD SOIL.

Insoluble	60.966
Silicic acid (sol. in sodic carbonate)	16.228
Sulfuric acid	0.247
Carbonic acid	1.750
Chlorin	none
Phosphoric acid	0.091
Lime	3.176
Magnesia	1.651
Ferric oxid	3.697
Potash	1.240
Soda	0.423
Aluminic oxid	3.746
Manganic oxid (br)	0.644
Moisture	2.070
Ignition (organic matter etc.)	4.412
	100.330

Additional Determinations.

Nitrogen	0.098
Copper	0.0058
Lead	0.0009
Arsenic acid	0.0011

According to this analysis we have an abundant supply of potash, a fair supply of phosphoric acid, more than an average supply of nitrogen for our soils and no possible deficiency except it be of chlorin, which is apparently absent; an aqueous extract of the soil, 25 grams, gives a faint reaction for chlorin, which simply means that it is present in very small quantities. This sample represents the

surface foot of soil taken at the place from which a dead tree had been removed. The determination of the water soluble portion, 0.22 per cent. does not indicate an excess of soluble salts. The history of this land shows that it is productive. A portion of it was at one time used as a vegetable or truck garden and produced well. The suggestion that the truck garden might have been heavily fertilized and thus forced into productiveness suggested itself at once and I urged it. The answer was the trees then should show where the truck garden was but they are neither better nor worse than in other portions adiacent to it.

We have no proof that starvation due to the infertility of the soil does in any measure account for the present conditions of the trees.

Another question somewhat more serious than the preceding is in regard to the presence of other poisonous substances besides those of the spray materials. This includes lead and copper. There is only one present which might possibly exercise a deleterious influence and that is lime. I have pointed out elsewhere that apple trees do well in limestone soils, at least they do not show the distress exhibited by the trees under consideration. We have no justification in fact, so far as I know, for assuming that lime as carbonate is injurious to apple trees and still less ground to assume that lime as a silicate is injurious, but a casual inspection of our analysis shows that the lime was probably present in both of these forms and possibly to a slight extent as sulphate.

So far neither the analysis of the soil nor the information received in regard to the garden crops grown give us the least reason for attributing the condition of the orchard to the infertility of the soil nor to any poisonous substances other than the spray materials or possibly to the simultaneous action of arsenic and lime, as has been pointed out under the latter subject.

The depth of the soil has been stated as given to me, but I doubt whether the soil is quite so deep as three to three and a half feet. I dug down to the bottom of the soil at some points and found it about two feet and then a marly subsoil.

I think it safe to assume that there is not lime enough in the soil to do any harm; further, I think it safe to assume that the depth of the soil is amply sufficient to grow healthy trees, provided that the subsoil is not in some way injurious.

I have tried to find out what is probably the greatest depth at which our apple trees feed, and judging by the depth at which I have found the fibrous roots under what I considered the most favorable conditions I would judge that depth not to exceed two and one-half feet. This depth of soil, then, would ordinarily be ample and I believe it is. If this be correct, the character of the subsoil lying below this depth, provided it was pervious to water, would probably not be of as great importance as we, at first glance, might think, for even if it contains arsenic, and I have strong reasons for believing that it does, this arsenic is at best difficulty soluble in water and lies below

the feeding ground of the trees. The question is an entirely different one when the subsoil is within 8 or 12 inches of the surface or the material constituting the subsoil is mixed with the soil to such an extent that it constitutes more than an eighth of the soil, as we sometimes find to be the case. We have in the analysis of this soil 1.739 per cent. of carbonic acid (CO_2) enough only to form a little less than 4 per cent. of calcic carbonate. This leaves a slight excess of lime to combine with the other acids. I have assumed this form of lime to exist in the soil as I take it that this is probably the most injurious form of lime usually met with in soils to which no arsenite of lime has been added or in which this salt does not exist. We do not positively know that carbonate of lime in such quantities is in the least injurious.

The trees in this orchard are sick. A few of the trees have corroded crowns. This feature is on the increase. Some trees have already been killed. There are some cases of bleeding and the deposits, like the others of this kind, are rich in arsenic and lime.

The trees not affected in either of these ways are small for their age and are not thrifty though the crowns are perfect. These trees have not suffered from fungi or insects or blight. There is no excessive water, nor is the soil in such condition as to produce suffocation. Neither Prof. Paddock nor Prof. Whipple was able to detect any cause for the condition of the orchard and tentatively suggested that it might be due to starvation. The small size of the trees, the color of their bark and the small annual growth justify the general conclusion that the trees lack in proper nutrition, but this does not explain whether this lack is due to an insufficient supply of food in the soil or an inability on the part of the tree to take up and assimilate the food. In so far as an analysis gives us any adequate information on this subject, this soil is fairly well provided with the various elements of plant food and if the trees are starving it is not because the supply of food within the reach of their roots is inadequate but because of some other reason. I believe that the trouble is due to the action of arsenic, either alone or in conjunction with the lime. This orchard has been well cared for and diligently sprayed for a number of years, using at first Paris green, next, lime, sal soda and arsenic, and of late years arsenate of lead.

I have shown that the soil, especially about the trees, is very rich in arsenic, as much as 138 parts arsenic acid per million of soil being present; also that distilled water dissolves out of this soil about 1.34 parts of arsenic acid. The rest of the soil is certainly heavily charged with arsenic, the sprayings having been frequent and heavy, placing it within reach of the feeding roots of the trees. That the trees may take up enough arsenic in this manner to do them injury is shown by the case of the elm tree and others which have been cited and there are still others which might have been mentioned. In addition we have two very significant facts, first that the trees are sick, second, that the wood of these trees contains arsenic, the one in which it was determined 2.19 parts per million of woody tissue, as much as is

usually found in other dying trees. In cases where arsenic is known to have been the cause of injury one of its effects has been to check the growth of the affected parts, in fact to almost prohibit it. These trees are small for their age, and make but little annual growth. All of the observed difficulties may be caused by arsenic and we find no other causes to which we can with any degree of reasonableness attribute the difficulty. We therefore conclude that systemic arsenical poisoning is very probably the cause of the unhealthy condition of these trees and in some cases of their death.

It is difficult to tell what part, if any, the lime may be playing in producing this specific trouble. I have stated that while it is well known that apple trees do well in limestone soils and that lime in the soil as carbonate of lime, this is the composition of our marls, is not per se injurious to the apple tree, yet the composition of the deposits formed by the bleeding described in Bulletin 131, and again in this, indicates strongly that lime, in some way, participates in producing it. Leaky spots in trees do not ordinarily, so far as my observation goes, give rise to such incrustations or form stalactites as we find on these apple trees. I have been unable to find an analysis of the ash of the apple tree juice and I have been unable to collect the juice in order to make one myself. I have, then, no data pertaining to this subject to serve for comparisons and can only present the facts.

In default of any knowledge concerning the composition of the juice of the apple tree, the best available subject from which to obtain some light would appear to be the ash of the wood on which there seems to be almost no data. I was able to find but one analysis of the ash of this wood and that is an old one, quoted by Adolph Mayer from the compilation of E. Wolf. This analysis shows the presence of over 36 per cent of silicic acid and can scarcely be considered as a typical ash. Dr. E. W. Allen was kind enough to call my attention to the analyses of apple tree ashes published in the report of the Director of the New York Experiment Station for 1891, page 164.

The trees subjected to investigation were young trees. The object in view was to determine the amount and character of the mineral constituents of plant food removed by nursery stock. The trees were probably not more than three or at most four years old. The trees discussed in this bulletin are of various ages, mostly from fourteen to eighteen years old. While I know nothing about the influence of the age of the tree upon the amount of ash in the wood and its composition, I will use these analyses for comparison for I have no others. Again the influence of the soil is a question which must be passed over. Another unavoidable condition which may affect the results is the necessity which compelled me to use small limbs one and a half to two inches in diameter to represent the living trees whereas I cut off a limb fully five inches in diameter at the trunk of the tree to represent the dead one. These are all weaknesses in our data but these data are the only available ones.

The soil in which two of the Colorado trees grew is represented by the analysis given under the caption "Analysis of a Marly

Soil." The third tree grew in a sandy loam, an alluvial soil, along the Gunnison river. The lime dissolved out of this soil by acetic acid was equivalent to 3.547 per cent of calcic carbonate. The subsoil is sandy and there is no marl present in the sense that we speak of its occurring in and beneath the mesa soils. In the former case, that of the soil in which the two trees grew, there is more than nineteen per cent of calcic carbonate and a still more marly subsoil, as against 3.5 per cent calcic carbonate and a sandy subsoil in the latter case. This is as marked a contrast in the character of the soils as is likely to be found in any county in Colorado, waste lands excepted. The localities from which they were taken are about four miles apart, so that the general conditions, climate, etc., are comparable. The trees taken for examination are of the same variety, the Jonathan. This variety was chosen because it seems to be the one which is most subject to these troubles.

The results of an examination of the quantity and composition of apple tree ashes given in the Report of the Director of the New York Station, Geneva, 1891, are as follows, taking the average for three varieties, Haas, Golden Sweet and Hurlburt:

	Branches	Trunks	Roots
Silicic acid	2.30	3.65	26.74
Phosphoric acid	5.89	4.94	7.11
Chlorin	0.68	0.43	0.37
Sulfuric acid	3.18	4.19	4.17
Carbonic acid	28.23	28.65	10.12
Ferric oxid	0.21	0.00	3.36
Calcic oxid (lime)	41.94	43.76	28.39
Magnesic oxid	6.99	6.38	8.17
Sodic oxid	4.86	2.57	5.28
Potassic oxid	5.71	5.43	5.76
	99.99	100.00	100.01

The percentage of ash in these trees was as follows: in the Hulburt 1.6, in the Haas 1.8 and in the Golden Sweet 1.2 per cent.

It was not feasible for us to obtain wood from the trunks of bearing trees. I had to content myself with the heaviest wood removed in pruning. This was branches varying from one and a half to two inches in diameter. In the case of a dead tree I took a large branch, at least five inches in diameter where I cut it from the trunk of the tree. These samples were taken on the 10th of February, 1910. The percentages of ash in the samples as received at the laboratory without drying were as follows, dead tree 0.964 per cent; living trees on marly soil, 2.00 per cent; and living trees on sandy loam on river bottom, 1.17 per cent. The dead tree had died during the early part of the preceding autumn. There were many leaves and nearly if not quite full grown apples still hanging on the tree. There were other trees of the same variety and in the next row presenting the same conditions. These conditions are mentioned because the ash constituents of the wood, such of them as are soluble, may have been used up in the effort of the tree to mature the crop of fruit. There is no way of telling how long the tree had been draw-

ing on this source of supply. The end result is all that we can definitely establish and this shows the presence of 0.926 per cent of ash. The trees growing on the river bottom, sandy loam soil, appear to be perfectly healthy. The growth is vigorous and the bark has a normal color. There are almost no signs of unhealthiness in this orchard that I saw or to which my attention was called. The orchard had been sprayed but not as regularly and persistently as the preceding one. The living trees from the preceding orchard are certainly more nearly comparable to these trees than the dead tree is because they are living trees and because the parts of the trees were of the same size and approximately of the same age. We find that the limbs of the trees growing on marly soil contain 2.00 per cent of ash while those growing on the sandy loam carry only 1.17 per cent. The average percentage of ash in the young trees grown at Geneva, N. Y., is 1.55 while the percentage in Colorado trees assumed to be normal is 1.17 per cent. The dead tree grown on marly soil contains a less percentage and the living tree a larger pencentage of ash than either the New York trees or the Colorado trees grown on a sandy loam soil. The New York trees were taken for examination early in the spring before the buds were well developed. They ought, therefore, to be comparable in this respect.

We see that the living trees on the marly soil contain 1.7 times as much ash as the trees growing on the sandy loam and 1.3 times as much as the young trees grown in New York. I have separated the bark from the wood and the statements of my further results are not directly comparable.

Wood of the dead tree, marly soil, 6464 grams, percentage of ash, 0.453, amount of ash obtained 29.28 grams. Bark from the wood of the dead tree, 624 grams, percentage of ash, 7.854, amount of ash obtained 49.00 grams. The percentage of ash in the bark is 17.3 times as great as in the wood. The percentage of insoluble ash in the bark is 18.35 times and that of the soluble ash 11.6 times as great as in the wood.

Wood of living trees, marly soil, 8760 grams, percentage of ash 0.539, bark 1516 grams, percentage of ash 10.452. Amount of ash obtained from wood, 47.22 grams, from bark 158.45 grams. The percentage of ash in the bark is 19.39 times that in the wood; that of the insoluble ash in the bark is 28.4 times and that of the soluble ash 6.5 times that of the wood.

Wood of healthy trees, sandy loam, 6794 grams, percentage of ash 0.389, amount of ash obtained 26.34 grams, bark 878 grams, percentage of ash 7.21, amount of ash 63.30 grams. The percentage of ash in the bark is 18.53 times that in the wood; that of the insoluble ash 24.93 times, and that of the soluble ash 6.18 times as great as that in the wood.

A comparison between the quantities of ash in the living trees from the marly soil and in those growing in a sandy loam shows a decidedly higher percentage, both in the wood and bark in the former

case than in the latter. The composition of these ashes is even more striking than their quantities. The ashes were prepared with great care and yet there was water present in some of them and there is a deficiency of carbonic acid. One of the samples was analyzed four times to be sure that no mistake had been made, the excess of bases and the presence of water could not be altered. The ashes had been treated with a solution of ammonic carbonate and subsequently heated to 210° C. with the addition of dry ammonic carbonate. The carbon, sand, and water have been deducted and the analyses stated on the basis of 100.

	Living tree Sandy Loam		Living tree Marly soil		Dead tree, Marly soil	
	Wood	Bark	Wood	Bark	Wood	Bark
Silicic acid	0.837	0.944	0.807	0.774	0.604	0.552
Phosphoric acid	5.094	3.170	4.524	1.500	3.170	1.234
Chlorin	Trace	0.195	Trace	Trace	0.406	0.135
Sulfuric acid	1.884	0.554	1.821	0.449	1.474	0.396
Carbonic acid	29.549	36.615	33.826	35.467	34.970	39.395
Lime	26.000	49.141	35.920	54.320	41.264	53.697
Magnesia	9.289	3.189	7.574	1.408	8.073	1.125
Ferric oxid	0.105	0.212	0.199	0.184	0.130	0.182
Manganic oxid	0.147	0.101	0.143	0.175	0.149	0.127
Potash	26.621	5.264	14.298	5.200	4.999	1.750
Soda	0.474	0.615	0.888	0.523	4.761	1.407
	100.000	100.000	100.000	100.000	100.000	100.000

As already intimated we do not know whether any of these analyses can justly be considered as representing the quantity and composition of the ash of a perfectly normal apple tree. The New York trees were young and the bark and wood were evidently taken together. The object that that station had in view did not require the examination of these parts separately.

We have seen that the limbs of the Jonathan trees growing on a marly soil contain 2.00 per cent of ash whereas the limbs of trees growing on a sandy loam, the bark included in both cases, contain only 1.17 per cent. We notice further that the wood of the trees growing on the marly soil is high in lime and low in potash compared with that grown on the sandy loam, the ash of the former contains 36 while the latter contained 26 per cent of lime; in regard to the potash the relative quantities are reserved, i. e., the ash of the former contains 14.3, that of the latter 26.6 per cent. The phosphoric acid of these ashes is much more nearly equal, 4.5 per cent in the wood grown on marly soil and 5.00 per cent in that of wood grown on a sandy loam. We find that the ashes of the barks also vary, that of the trees growing on the marly soil being very rich in lime, 54.3 per cent, while that of the trees grown on sandy loam contains 48.2 per cent. The phosphoric acid is twice as great in the ash of the bark from trees grown on sandy loam as on the marly soil. The results obtained for the quantity of ash present in the wood and bark of the dead tree and its composition seem to show mostly the extent to which the tree used up its ash constituents in dying.

The analyses of the ashes given in the New York report are of

young trees which may make some difference, but they are similar to ours only in containing a high percentage of lime. The potash in them is only a few tenths of one per cent higher than we find in the ash of our dead tree. I have no analysis of the Geneva soils though some were published in Bulletin 56, old Series.

The effect of the marly soil seems to be to increase the percentage of ash in the wood and bark, to lower the percentage of potash present and to increase that of the lime. This marly soil has been sprayed regularly and heavily. The results give no conclusive answer to the question had in mind when the work was undertaken, but the following facts present themselves. The trees grown on the sandy loam are thrifty and healthy so far as we are able to judge. The trees on the marly soil on the other hand are not thrifty. We find no bleeding in the case of the trees on the sandy loam while it is quite common in the trees on marly soils. The ash of the trees grown on the sandy loam contains much less lime and more potash than that of trees grown on marly soil. The deposits made by exuding juices of the bleeding trees contain 25.0 per cent. of lime and 49 parts of arsenic acid per million. These facts perhaps may not amount to satisfactory proof to some but they certainly point directly to either the lime or the arsenic or to their joint action as the cause of the unhealthy condition of the trees. As lime alone has not been observed to produce these results, confined almost exclusively to these marly soils, we are justified in attributing the trouble to their joint action.

I cut off the limb of a Jonathan tree on the 8th of April and on the 12th of May I removed 2.2 grams of a deposit. The aqueous solution of this deposit gave a very satisfactory test for arsenic. The trunk through which the juice had to pass was very short and the arsenic could scarcely have been gathered from the woody tissues of the tree. The elm root, taken at least six feet from the trunk, was quite rich in arsenic. No doubt can reasonably be entertained but that this arsenic and also the lime had been gathered by the roots. The cases mentioned are by no means isolated ones. In some orchards cases of bleeding are numerous and severe, in others they may be absent. The orchards in which this occurs usually have a marly subsoil at a shallow depth. This bleeding is not confined to wounds made by trimming but frequently takes place from cracks in the bark as previously described. Some instances of this are met with in many of the orchards to which reference has been made.

Healthy trees do not bleed in this manner and their juices do not form such deposits. Trees killed by irritant arsenical poisoning do not bleed in this manner, nor have I seen any deposit of this sort on trees injured by arsenic accidentally applied to them. This condition is not attributable to arsenical poisoning alone. This deposit is, however, rich in arsenic and lime and I infer from these facts that we have in these cases a systemic poisoning by lime and arsenic.

It has been observed by orchardists that certain shallow soils underlaid by marl produce a yellowing of the leaves on apple trees;

this has been attributed to the lime. I have held in these cases that it was starvation rather than poisoning but this cannot be admitted in the case of the soil, an analysis of which has been given on a preceding page, without denying the evidence of this analysis and the actual productiveness of the soil.

I have intentionally permitted these two subjects, the systemic poisoning by arsenic and the effects of lime, to merge into this broader form, because I believe that this form of the trouble is primarily due to arsenical poisoning modified by the presence of lime which exists in the soil in large quantities in the form of calcic carbonate and often forms, beneath the soil proper, a layer from two or three inches to two or more feet in thickness.

I have shown on a previous page that these limey, virgin soils and also these marls contain arsenic, about one-tenth as much as the average orchard soil examined.

To restate the case briefly. We have well cared for trees which are extremely small for their age. Their general condition is bad; some of the trees have died, these trees had no disease of the crown or roots and were not suffering from any recognizable, known disease; the wood is stained a light brown, an effect produced by arsenic; they make but little growth, another effect produced by arsenic; arsenic is present in the woody tissues of these trees and even in their fruit. Some of the trees have corroded crowns, a sufficient cause to account for the death of the particular trees. These cases are not considered in this place. It will be recalled that in discussing irritant arsenical poisoning I pointed out that some of the arsenic found was probably gathered by the roots. Some of the trees show the splitting of the bark and bleeding, forming deposits rich in arsenic and lime.

The arsenic is gathered from the soil by the roots as is shown by the peach trees and also by the elm which were never sprayed. This fact is again shown by the presence of arsenic in the fruit and leaves grown on trees which have not been sprayed this year. This arsenic is evidently carried to the leaves and the fruit from the soil by the solutions passing through the tree. The final question is how much arsenic can a tree tolerate and how long can it endure the amount that the roots gather and pass into the tree. These are questions to be solved. I am convinced that many trees have already reached the limit of their endurance and that this is the cause of their bad condition. I said in Bulletin 131, in reference to this subject of systemic poisoning and the action of lime as distinct from irritant arsenical poisoning, "These trees do not present the symptoms described for arsenical poisoning, though arsenic is very abundant. * * * These soils are marly or have a subsoil of this material and the presence of 25 per cent of lime in the dried sap seems to me to be a very suggestive fact."

I add to this that the presence of arsenic in these soils equivalent to from 26 to 138 parts of arsenic acid per million of soil, and of arsenic equivalent to 49 parts of this acid to each million parts of this dried

juice are more suggestive and that the presence of arsenic in leaves which have received no application of spray equivalent to 2.19 parts of arsenic acid per million of dried leaves and in the fruit equivalent to from 0.51 to 2.3 parts of arsenic acid per million of fresh fruit, are still more suggestive, if not satisfactorily conclusive, that systemic arsenical poisoning is really the cause of the small size, the bleeding and the death of some of our fruit trees.

Before I state the conclusions of this bulletin it is proper that I should express my appreciation of the helpful, kindly interest and willing assistance rendered me by the officers and others connected with this station and also to officers of other stations and states.

Throughout Bulletin 131 I tried to make it as plain as language could possibly make it that I fully appreciated the fact that the subject matter of the bulletin was of the most serious character and of very great importance. I told the public that my colleagues had urged me to take up the investigation and used this language: "These statements are not made to devolve any responsibility upon these professors, but to show that this view has not been hidden from the people or my colleagues and the presentation of this bulletin is not a hasty resolve or a thing done without a very keen appreciation of its importance not only to the orchardists of Colorado, but to all orchardists." The same is true in regard to this bulletin.

It is true that the presence of arsenic in apples from California, Michigan, New York, Pennsylvania, Ohio, Illinois, and Colorado show that fruit grown on sprayed trees contains arsenic and further that this is a general fact, but there is no reason at all for alarm for either the health or life of persons eating such pears or apples. Two of my assistants and I have tried it, one of us eating nearly eight pounds of apples by weight, in twelve hours. The apples from Illinois, Ohio, and New York were just as rich in arsenic as those from California or Colorado. I repeat that so far as the public is concerned there is no reason at all for the least concern. At present it seems possible that we may use the sulfid of arsenic with less danger than accompanies the use of lead arsenate and we will certainly use very much less arsenic than in the past. It has been demonstrated that if everybody will give his orchard one thorough spray at the time now recommended, using one or one and one-fourth pounds of pasty lead arsenate to fifty gallons of water, four to four and one-half pounds to the 200 gallon tank, we will have fairly clean apples. The preceding statement applies only under favorabe conditions. There can be no doubt but that excellent results have been and may be obtained from one spray but there are conditions under which one spray will not suffice to supress the injury by the codling moth even to a reasonable limit. It seems that the first brood may be so long in making its appearance that one may find unhatched eggs and pupated specimens representing the first brood on the same date.

The growing apples present a comparatively large amount of surface entirely free from the arsenate of lead and consequently not protected against the attack of late hatching individuals. These are not theoretical considerations but facts as they have been observed in the orchard were may be found, in some sections, many apples which the worms of the first brood have entered from the side. In such cases one spraying would mean a wormy crop. On the other hand the results obtained with one spraying have been excellent, especially in cases where the orchard was not subjected to subsequent infection from adjacent, unsprayed, or very poorly sprayed orchards.

Summary

While many trees, both apple and pear, have been damaged, even killed, by the action of arsenic collected about the crown or collar of the tree, other causes of death are not excluded. It is shown in Bulletin 155 that nitre in the soil may kill apple trees, but the crowns and roots are not attacked by this agent as they are by arsenic.

The total number of trees affected is large. It is seldom that more than a few affected trees occur together, usually they occur singly, scattered throughout the orchard.

Trees killed by nitre usually occur in blocks, sometimes only a few trees, 12 to 20, but in other instances they occur by the acre.

The arsenical preparations used for spraying are supposed to be insoluble in water, this is not correct. Well washed arsenate of lead will yield arsenic acid to pure water, about, 0.3 per cent. of its dry weight.

The addition of sodic sulfate, sodic chlorid or sodic carbonate, even in small quantities, to the water materially increases the amount dissolved. This is especially true of the sodic chlorid and sodic carbonate .

In Bulletin 131, I attached considerable weight to the action of these alkali salts which are present in all of the soils of the semi-arid regions in a greater measure than in the soils of some other sections. I do not doubt but that they have some influence upon the solubility of the arsenical compounds, but as much as 1.38 parts of arsenic acid per million soluble in water has been found when the total water-soluble portion amounted to only 0.22 per cent. of the air dried soil. Again I have found weighable quantities of water soluble arsenic in soils which were free from alkali. The alkalis in our soils may increase but they are not the only cause of the solubility of the arsenic.

Three forms of this trouble are recognized, corrosive arsenical poisoning, systemic arsenical poisoning and arsenic-lime poisoning. The last form is consdered as being produced by the joint action of lime and arsenic, because we do not find this trouble present on limestone soils in general nor is it characterstic of arsenical poisoning produced by soluble arsenic preparations, sodic arsenite for example.

Corrosive arsenical poisoning attacks the tree at the crown, below the surface of the soil and usually involves the large roots also. The attack is from the outside and causes the disintegration of the bark, the cambium is not destroyed until the corrosion has perforated the bark which is not loosened. Pear and apple trees are affected; the pear tree is, at least, as susceptible to the action of the arsenic as the apple tree. Some varieties of pears, as well as apples, seem more susceptible than others, but this is true only in a general way. The age of the tree at the time the first applications were made seems to have some effect upon the resisting power of the bark. The variety of soil may have some influence but it is not pronounced enough to be recognized with certainty. Very many, if not the greater part of our soils, contain arsenic. This is true of our virgin soils as well as of our cultivated soils. Our orchard soils now contain from 10 to 28 times as much arsenic as our virgin soils.

No other agency known to us produces the observed results, but arsenic when applied in soluble form produces similar effects quickly.

The first sign of trouble in the apple tree is an early ripening of the leaves, at least, one year before the death of the tree; in pear trees the foliage ripens early and assume a deep purple color.

The amount of arsenic present in the destroyed bark and in the woody tissues of such trees is as great as in cases in which it is known that arsenic was the cause of death.

The trouble is very general throughout the state and occurs in all kinds of soils which fact eliminates the question of seepage and, to a large extent, that of alkalis.

While the alkalis may in some instances be present in the soil in sufficient quantities to produce a perceptible effect, we cannot, owing to the wide range of localities and the great variety of soils in which we meet the trouble attribute very great importance to their action. Their presence, however, in soils undoubtedly tends to make the arsenic more readily soluble.

In the case of trees which have not been sprayed but which have been grown as fillers in sprayed orchards, the wood contained arsenic. This is true, too, of young trees grown in soil which contains arsenic. This shows that the arsenic may be and is taken up with the nitrient solutions. The fruit grown on such trees, apples and pears, contain arsenic and also the leaves. The fruit and leaves grow and are shed each season this is not the case with the woody portions of the tree.

Systemic poisoning is produced by this arsenic distributed throughout the tree, interfering with nutrition and growth of the tree and in some cases causing its death.

The bleeding met with in trees on marly soils is probably due to the combined action of lime and arsenic. A study of the ash constituents contained in the wood of trees grown in marly soil and in a sandy loam shows a remarkable difference in the amount of ash, 2.00 per cent. against 1.17 per cent. of the wood and a very much lower percentage of potash, 14.-298 per cent. against 26.621 per cent. of ash. The deposit produced by this bleeding is very rich in arsenic as it contains 49 parts of arsenic acid per million of the dried deposit.

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

A BACTERIAL DISEASE OF ALFALFA

BY

WALTER G. SACKETT

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Out of twenty-one infected stems examined and plated at different stages of the disease, thirteen gave pure cultures of this colony in the Petri dishes. In seventeen plates, it was the dominant colony. Platings from five different leaves gave pure cultures in three cases and in four out of five the above colony was the most abundant. In other words, pure cultures were obtained in 62 per cent of the original isolations and in 81 per cent this white colony was dominant. In two out of twenty-six isolations or in seven per cent, it was absent. Plates made from the moist or freshly dried exudate, as a rule, gave pure cultures of the same organism.

An examination of the following notes, made in connection with some of the isolations, may be of interest in showing with what degree of purity the organism can be isolated from field material.

Plates made from material collected at Gypsum, Colorado, May 25, 1909. Plated in Nutrient Agar May 27, 1909.

I. Petiole.—Culture pure; growth after 72 hours; culture picked up 6-1-09. Colony round, smooth, grayish white, glistening, slightly raised. Stained film preparation from four day old colony; short rods, medium thick, mostly single, occasionally in twos, slightly curved and wedge shaped; stain readily with ordinary aqueous fuchsin.

II. Leaf.—Culture pure; characteristic white colony; growth after 72 hours; culture picked up 6-1-09. Colony and stained film same as Petiole above.

III. Stem Tissue—New Infection.—Culture pure; characteristic white colony; growth after 72 hours; culture picked up 6-1-09. Colony and stained film same as Petiole above.

IV. Stem Tissue.—Culture pure; characteristic white colony; growth after 72 hours; culture picked up 6-1-09. Colony and stained film same as Petiole above. Orange colonies appeared on June 5th; picked these up.

V. Stem Tissue—Black.—Culture mixed; growth after 48 hours; cultures picked up 6-1-09. Yellow colonies dominant; few white colonies which resemble those described from petiole.

VI. Exudate Scale No. 1.—Culture pure; growth after 72 hours; culture picked up 6-1-09. Characteristic white colonies same as petiole but germs themselves seem shorter, less curved and wedge shaped. Later observations have shown this germ to be the same as the petiole culture.

VII. Exudate Scale No. 2.—Culture pure; growth after 72 hours; culture picked up 6-1-09. Characteristic white colonies; germ same as that described from Exudate No. 1.

In all probability, all of the above characteristic white colonies were the same. Slight differences in staining seemed to make some difference in the size and shape of the organism itself. In every case the germ is a short, medium thick, motile rod with rounded ends and with a tendency to produce slightly curved forms which show granules on staining.

Plates made from material collected from the Experimental Plats at Gypsum, Colorado, June 11, 1909, and plated June 14, in nutrient agar. Notes taken June 19, 1909.

I. Stem Yellow—Typical.—Plate pure; growth just visible after 48 hours, good after 72 hours; culture picked up 6-19-09. Colony round, smooth, grayish white, glistening, slightly raised, margin entire to undulate. Stain: rods, short, moderately thick, rounded ends, many wedge shape and curved.

II. Stem Advanced.—Plate pure; white colony same as "stem yellow" above. Growth just visible after 48 hours, good after 72 hours. Stain: same as "stem yellow." Culture picked up 6-19-09.

III. Stem Brown.—Plate pure; white colony same as above; growth and stain same; culture picked up 6-19-09.

IV. Stem Green.—Plate contained the same white colony, but an orange colored colony dominated; this orange colony (1) previously shown not to be the cause of the trouble. No cultures picked up.

V. Stem Yellow No. 2.—Plate mixed; the same white colony dominated; there was also the above mentioned orange colony and a large yellow one found once before in earlier plates (2). No cultures picked up.

VI. Stem Watery.—Plate pure; white colony same as above; growth visible after 48 hours, good after 72 hours. Stain: same as "stem yellow" above; short, curved rods, wedge shape and irregular. Cultures picked up 6-19-09.

VII. Single Stoma—Old Infection.—Plate pure; white colony and stain same as "stem yellow" above. Growth visible after 48 hours, good after 72 hours. Culture picked up 6-19-09.

(1) Stem tissue—plates of May 27, 1909.

(2) Stem tissue black—plates of May 27, 1909.

VIII. Stomata—New Infection.—Plate pure; white colony and stain same as "stem yellow" above. Culture picked up 6-19-09.

IX. Stomata—Black.—Plate pure; white colony and stain same as "stem yellow" above. Culture picked up 6-19-09.

All of the cultures picked up from the dominant white colonies, present in all of the plates, have been shown to be one and the same organism and when inoculated onto alfalfa plants, all are capable of producing the disease.

Inoculations have been made upon alfalfa plants, grown under greenhouse conditions, with the three different cultures which have been isolated during this investigation, namely, the characteristic white one, the yellow and the orange, and the only one which has produced typical symptoms of the disease, in fact the only one which has produced any pathological condition whatever, is the dominant white colony referred to so frequently above. Cultures obtained from stem, leaf, petiole, or exudate, were equally pathogenic. Detailed descriptions of this part of the work are given on page 24 under "Greenhouse Experiments."

In order to establish further the fact, that this germ was the unmistakable cause of the trouble, an alfalfa plant was inoculated June 7, 1909 with our present stock culture of the causal organism, to which the name *Pseudomonas medicaginis*, n. sp. has been given, which was isolated from an infected stem May 27, 1909. By June 19, typical symptoms had developed, and plates were made from the yellowish green, watery tissue. On June 21, the Petri dishes showed a pure culture of the same white colony and the organism

5
4
3
2
1
MAPalmer

was reisolated on an agar slant. When compared with the original culture, the recovered organism was identical both in the hanging drop and when stained with aqueous fuchsin. The reisolated culture was again inoculated, June 25, by needle pricks into three different stems, and all of the inoculations gave positive results; the needle pricks showed a yellow, watery zone around the point of infection after nine days, and later turned black. When material from these diseased areas was examined microscopically, August 16, the same milky cloud appeared in the mount as has been described for field material, and swarms of motile rods were visible.

In all, one hundred and two inoculations have been made with this culture, introduced either by scraping the stem or by needle pricks, and positive results have been secured with one hundred per cent of the infections. Control inoculations with a sterile needle have been carried along with all of the experiments, and in no case have any of the check plants developed symptoms of the disease.

METHOD OF INFECTION.

In an effort to secure a satisfactory explanation of the method of infection, the writer spent over a month in the field where the disease is most prevalent. As a result of the daily observations and the gross and microscopic examination of more than three hundred plants, collected at all stages of the disease, before it made its appearance and until it was flourishing, he believes the following to be the most tenable and satisfactory solution of the question.

This phase of the investigation was carried on at Gypsum, Colorado, where our first observations were taken May 4, 1909; this was early in the spring for this locality and altitude (over 6,000 feet above sea level). The season was considered cold and backward, and a moderately heavy snow had fallen one week before; traces of this were still to be seen in the valleys, and the surrounding hills and mountains were heavily covered.

The alfalfa was just beginning to grow, the average height in the diseased fields being from 1½ to 2 inches. Most of the plants had a yellowish green color due, presumably, to the cold. An examination of the young, succulent shoots showed that the epidermis of practically every one of them was wrinkled just below the point of attachment of the first four or five leaves, and often this wrinkling extended half way to the next leaf below. The epidermis was loose from the tissue beneath and appeared to be too large for the stem. When this was peeled off, the underlying tissue had a yellowish, green color much like the diseased plants, but a microscopic examination of such material failed to show any micro-organisms present. In those parts of the stem where this wrinkling

was absent, the tissue beneath the epidermis was not yellow, but a whitish green. In many plants, the loosened epidermis had the appearance of partially collapsed blisters, while around and underneath these blisters the tissue seemed darker than normal and watery, with a suggestion of its having been frozen. Numerous lenticular breaks occurred in the epidermis of some stems. These might have been due to insect work although rather early in the season for this. Occasionally stems were found where the wrinkled epidermis had split open for a distance of one centimeter, exposing the moist pyrenchyma beneath.

Ten days later, May 14, the epidermis of practically every stem in the field was split wide open from node to node over the first six internodes, the third to the fifth internodes being the most common. This splitting appeared to have begun with the wrinkled epidermis mentioned above, and had extended the whole length of the internode thereby exposing the succulent, moist tissue beneath to infection. It is the concensus of opinion of those who have observed this phenomenon, that both the breaking away of the epidermis from the underlying tissue and the wrinkling and subsequent splitting are caused by freezing. A similar trouble ascribed to freezing has been observed in cherry trees and less frequently in the apple. Here the bark cracks and later splits open, exposing the green wood beneath just as in the alfalfa stems.

Anyone who has ever lived in Colorado is familiar with the soil carrying capacity of our winds, and with this in mind, it is easy to understand how germ laden soil might be blown into these cracks, where it would adhere to the moist, exposed surface, and bring about a fatal inoculation. As a matter of fact, soil was always found adhering to these surfaces, and, already, typical cases of the disease were developing. A microscopic examination of the tissues from the injured areas usually showed the germs to be present in great numbers, while ten days previous, that is before the splitting had occurred, there was no indication of any infection. Invariably, the disease appeared first and was worst on those parts of the stem where the epidermis had split and where soil had been caught in the open wound. A striking example of this was seen in an alfalfa field adjacent to a field which had been cultivated recently and sown to oats. The oat field was on the windward side, and with every gust, quantities of fine soil were carried over into the alfalfa. All along this side of the field, there was an aggravated attack of the disease, extending twenty to thirty feet into the alfalfa and the whole length of the field. Every plant was gray with soil and it is only reasonable to suppose that the disease was more severe here than in the more remote parts of the field because of the heavier soil inoculation.

This explanation satisfies one of the most difficult questions which has arisen in connection with the problem, namely, why does the first cutting, alone, suffer from the attack? There are never any frosts after the first crop is out of the way, and consequently there are no split stems in which to start the infection.

In a preliminary report (1), the writer has suggested that possibly the constant tramping of cattle and horses, pastured on the alfalfa fields during the winter, might have split open the crowns and bruised the young, tender shoots so that during the first irrigation, soil containing the disease germs was washed into the injured tissue and started the trouble on the first cutting. Our observations during the past season do not warrant such a conclusion in the majority of cases at least, since, in the first place, the disease was active at least two weeks before the first irrigation, and in the second place, our experimental plats, to which stock had no access, suffered just as severely as the fields which were pastured.

Not infrequently, we find the disease at work on stems where there has been no apparent previous injury to the epidermis; sometimes this assumes the form of a continuous, unbroken infection of the whole internode, and again it occurs as separate, punctiform lesions giving the stem a speckled appearance. This last condition would seem to indicate an infection through the stomata, and inasmuch as we have been able to secure successful inoculations in the greenhouse by applying the culture to the unbroken epidermis, it is altogether possible that stomatal infections take place under field conditions. The leaflets often exhibit yellowish, watery areas along the margin and the larger veins when there is no evidence of the trouble in any other part of the plant; again, the tiny petioles succumb to the disease independently of either the stem or the attached leaflets. Water pore and stomatal infection similar to that described for the black rot of cabbage may explain these cases.

There are doubtless other ways in which infection can take place, but the methods described above, especially the inoculation through the split epidermis, seem to be the most common. It is possible that added observations of another season will give us more light upon this point and so rather than draw any final conclusion as to the *one way* in which inoculation takes place in the field, we prefer to leave the question open.

DESCRIPTION OF THE CAUSAL ORGANISM.

Pseudomonas medicaginis, n. sp. (Sackett.)

I. MORPHOLOGY

1. Vegetative Cells.

When grown upon nutrient agar for 24 hours at 28° C., and

(1) Bulletin 138, Colo. Exp. Sta., Jan. 1909.

stained with aqueous fuchsin, the organism is found to be a short rod with rounded ends, for the most part single, more rarely in short chains of four to six elements, and occasionally in long filaments. Many of the rods appear slightly curved and wedge shaped; the rods taken directly from diseased stems are usually shorter, and when stained with aqueous fuchsin, appear to take the stain more deeply at the poles.

The individual rods usually measure about 1.2 to 2.4μ x .5 to .8μ; the majority are about 2.1μ x .7μ; the filaments vary in length from 20.2μ to 37.2μ.

2. Sporangia.

No sporangia have been observed.

3. Endospores.

No endospores have been observed in agar cultures four months old.

4. Flagella.

When stained by Loeffler's (1) method, it was possible to demonstrate from 1 to 4 flagella attached to each pole. Following Migula's classification, this bi-polar attachment of the flagella places the organism in the genus **Pseudomonas.** A 24 hour agar

(1) Centralbl. f. Bakt., 1889, 6, p. 209; 1890, 7, p. 625.

culture, examined in the hanging drop, exhibits very actively motile rods with rounded ends, from two to four times as long as broad, and which occur, for the most part, singly and occasionally in short chains and filaments.

5. Capsules.

No capsules have been observed when stained by Welch's method. (2)

6. Zoogloea.

No zoogloea have been observed.

7. Involution Forms.

Films made from an agar culture four months old and stained with carbol fuchsin show many degenerative forms. Long irregular rods which stain unevenly, giving a granular appearance, and usually darker at the poles, are among the most common. No unusual or strikingly characteristic forms have been observed.

8. Staining Reactions.

The organism stains readily with the ordinary aqueous stains, anilin gentian violet, and carbol fuchsin.

Gram's Stain.

The results from repeated efforts at staining by Gram's method were not sufficiently sharp and decisive to warrant any positive conclusions; the stain was neither entirely lost nor was it retained in its original depth and brilliancy. Both the anilin gentian violet and the iodine solution were used for one and one half minutes and the preparations were left in absolute alcohol for five minutes. When examined, the germs were distinctly stained, but not as intensely as those which had not been treated with the alcohol and for this reason, alone, the organism is here reported as Gram negative, while in reality it is neither positive nor negative.

Loeffler's Methylene Blue.

Stained with Loeffler's methylene blue, the protoplasm of the organism appears very coarsely granular, so much so, in fact, as to give the rods almost a striated appearance.

Neisser's Stain.

Neisser's stain brings out a more or less granular structure to

(2) Bull. Johns Hopkins Hosp., 1892, 3, p. 128.

the protoplasm, but no definite meta-chromatic or polar granules are demonstrable.

II. CULTURAL FEATURES

1. Agar Stroke. Nutrient Agar.

GROWTH, at 27°-28° C., moderate in 24 hours, abundant after 72 hours; no growth at 37° C.
FORM OF GROWTH, filiform becoming more or less echinulate with age.
ELEVATION OF GROWTH, slightly convex.
LUSTER, glistening.
TOPOGRAPHY, smooth.
OPTICAL CHARACTERS, translucent.
CHROMOGENESIS, § grayish white, Engine color No. 12.
ODOR, absent.
CONSISTENCY, butyrous.
MEDIUM, light fluorescent green on the third day.

2. Potato.

GROWTH, scanty in 48 hours, moderate after 6 days.
FORM OF GROWTH, filiform becoming more or less echinulate with age.
ELEVATION OF GROWTH, slightly convex.
LUSTER, glistening.
TOPOGRAPHY, smooth.
CHROMOGENESIS, cream; best described as the color of light manilla paper; color lies between Orange Yellow Tint No. 2 and Engine Color No. 1. After 8 days, the color deepens to Orange Yellow Tint No. 2, and after 12 days, resembles most nearly Engine Color No. 7.
ODOR, absent.
CONSISTENCY, butyrous and slightly viscid.
MEDIUM, grayed and darkened.

3. Loeffler's Blood Serum.

STROKE, moderate in 3 days at 28° C.
FORM OF GROWTH, filiform.
ELEVATION, slightly convex.
LUSTER, glistening.
TOPOGRAPHY, smooth.
CHROMOGENESIS, grayish white.

4. Agar Stab.

GROWTH, best at top; surface growth moderate in 48 hours, abundant after 4 days; surface growth restricted.
LINE OF PUNCTURE, papillate; no liquefaction.
CHROMOGENESIS, grayish white, Engine Color No. 12.
MEDIUM, fluorescent at the surface on the third day.

5. Gelatin Stab.

GROWTH, best at top, no growth in the lower half of the stab.
LINE OF PUNCTURE, filiform to papillate.
LIQUEFACTION, none.
MEDIUM, unchanged.

6. Nutrient Broth.

SURFACE GROWTH, pellicle on the third day.
CLOUDING, slight in 24 hours, moderate in 48 hours, never strong; persistent; fluid slightly turbid.
ODOR, absent.
SEDIMENT, compact, slightly viscid on agitation, scant.

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§ Color terms refer to Standard Colored Papers made by Milton Bradley Co., Springfield, Mass.

7. Plain Milk.

No visible change takes place in the milk in 30 days; there is no peptonization, no coagulation; the reaction becomes neutral to phenolphthalein after 40 days. Reaction after 1 day, +12, after 2 days, +10, after 4 days, +8, after 10 days, +5, after 20 days, +2. The medium is unchanged in color; there is no curd formation and no peptonization at the expiration of 30 days.

8. Litmus Milk.

No change observed until the sixth day when the litmus appears somewhat lighter in color; by the seventh day it becomes bluer and by the fourteenth day it is intense blue. At the end of twenty days, it has the same deep blue color; there is no curd formation and no peptonization at the expiration of 30 days. There is no reduction of the litmus at any time.

9. Gelatin Colonies. Eight days old.

GROWTH, slow, 20° C.
FORM, round.
ELEVATION, slightly convex.
EDGE, undulating.
LIQUEFACTION, none after twenty days.

10. Agar Colonies. Five days old.

GROWTH, slow at 25° C. Fine white colonies visible to the eye after 48 hours.
FORM, round.
SURFACE, smooth, glistening, concentrically ringed.
ELEVATION, convex.
EDGE, entire to undulate; flattened sides.
INTERNAL STRUCTURE, more coarsely granular and denser at the center becoming more finely granular and less dense at the margin.
CHROMOGENESIS, grayish white, Engine Color No. 12.
SIZE, medium, average 1.5 m.m.

11. Glycerine Agar. Agar stroke.

GROWTH, at 27°-28° C., slight in 24 hours; moderate in 48 hours.
FORM OF GROWTH, filiform becoming more or less papillate with age.
ELEVATION OF GROWTH, slightly convex.
LUSTER, glistening.
TOPOGRAPHY, smooth.
OPTICAL CHARACTERS, translucent.
CHROMOGENESIS, grayish white, Engine Color No. 12.
ODOR, none.
CONSISTENCY, butyrous.
MEDIUM, very light fluorescent green on the third day; not as deep a green as nutrient agar.

12. Alfalfa Agar. Agar stroke.

GROWTH, slight growth in water of condensation at base of stroke atfer 5 days; slight along line of inoculation in 12 days.
FORM OF GROWTH, filiform.
ELEVATION OF GROWTH, slightly convex.
LUSTER, glistening.
TOPOGRAPHY, smooth.
OPTICAL CHARACTERS, nearly opaque.
CHROMOGENESIS, Green Yellow Tint No. 2. Growth studded with fine black particles as if sprinkled with pepper.

ODOR, none.
CONSISTENCY, butyrous.
MEDIUM, surface becomes clouded as if a very fine precipitate had been formed in the medium as a result of the growth.

13. Synthetic Agar Low in Nitrogen. Agar stroke.
GROWTH, at 27°-28° C., moderate in 24 hours; very abundant after 3 days.
FORM OF GROWTH, filiform.
ELEVATION OF GROWTH, decidedly convex.
LUSTER, glistening, watery.
TOPOGRAPHY, smooth.
OPTICAL CHARACTERS, transparent; resembles boiled starch.
CHROMOGENESIS, watery white.
ODOR, none.
CONSISTENCY, butyrous or more exactly the consistency of starch jelly.
MEDIUM, no change.

14. Cohn's Solution, 28° C.
GROWTH, absent.
FLUID, no growth.

15. Uschinsky's Solution, 28° C.
GROWTH, slight in 24 hours, moderate in 3 days, abundant in 10 days.
FLUID, viscid sediment after 4 days; clouding, strong, persistent, fluid turbid. Light green after 21 days.

16. Dunham's Solution, 28° C.
GROWTH, moderate.
CLOUDING, moderate, persistent, fluid slightly turbid.

17. Asparagin Solution, 28° C.
GROWTH, abundant.
CLOUDING, moderate, persistent, fluid turbid.

18. Nitrate Broth, 28° C.
GROWTH, moderate.
CLOUDING, moderate, persistent, fluid slightly turbid.

19. Dextrose Bouillon, 28° C.
GROWTH, abundant.
CLOUDING, strong, persistent, fluid turbid.

20. Saccharose Bouillon, 28° C.
GROWTH, abundant.
CLOUDING, strong, persistent, fluid turbid.

21. Lactose Bouillon, 28° C.
GROWTH, abundant.
CLOUDING, strong, persistent, fluid turbid.

22. Maltose Bouillon, 28° C.
GROWTH, abundant.
CLOUDING, strong, persistent, fluid turbid.

23. Glycerine Bouillon, 28° C.
GROWTH, abundant.
CLOUDING, strong, persistent, fluid turbid.

24. Mannite Bouillon, 28° C.
GROWTH, abundant.
CLOUDING, strong, persistent, fluid turbid.

25. Growth in Bouillon Over Chloroform.
GROWTH, absent. 1 c.c. of chloroform was added with a sterile pipette to 10 c.c. of sterile bouillon in a test tube and after the chloroform had collected at the bottom of the tube, the broth was inoculated with two loops of a 24 hour broth culture.

26. Sodium Chloride in Bouillon.

The effect of sodium chloride upon growth has been determined by inoculating tubes of nutrient broth (+15° Fuller's Scale), containing different amount of chemically pure sodium chloride, with two loopfuls of a 24 hour broth culture. A preliminary test in which the broth contained from 0 to 12 per cent of salt, each tube differing by 1%, showed that the toxic strength lay somewhere between 3 and 4 per cent. In the next determinations, the tubes contained 3.0, 3.25, 3.5, 3.75 and 4 per cent of NaCl respectively. This same series was repeated three times with the result that growth took place in the presence of 3.75 per cent of NaCl, but **4 per cent was sufficient to inhibit it.**

27. Nitrogen.

Nitrogen has been obtained from **peptone, asparagin, glycerine, and beef broth,** but not from ammonium tartrate. No determinations have been made with other ammonium salts, urea or free nitrogen. An abundant growth has been obtained on a synthetic agar low in nitrogen, such as is used for growing the nodule forming bacteria; this would seem to indicate the possibility of the organism being able to utilize atmospheric nitrogen. Determinations of this particular feature are in progress at the present time.

28. Best Media for Long Continued Growth.

Standard nutrient agar with a reaction of +15° Fuller's scale has proved entirely satisfactory.

29. Quick Tests for Differential Purposes.

Fluorescent green color produced in the nutrient agar streak; no growth at 37½° C.; non liquefaction of gelatin; surface pellicle on nutrient broth; luxurient and characteristic growth on synthetic agar low in nitrogen (q. v.).

III. PHYSICAL AND BIOCHEMICAL FEATURES

1. Gas Production.

Four fermentation tubes, each, of dextrose, saccharose, lactose, maltose, glycerine and mannite broth were inoculated with a 48 hour culture; two of each were kept at 28° C. and two at 37½° C. Those held at 28° C. gave growth in the open arm after 24 hours, but none in the closed arm and no gas; those at 37½° C. showed no growth whatever. The turbidity in the open arm of those kept at 28° C. increased with age, extending over half way into the U, but at the end of ten days there was **no growth in the closed arm** and **no gas.** There was a well defined line between the growth in the bulb and the clear liquid in the closed arm, which seemed to point strongly toward the aerobic nature of the organism.

2. Production of Acid and Alkali.

60 c.c. portions of dextrose broth, saccharose broth, lactose broth, maltose broth, glycerine broth and mannite broth in 200 c.c. Erlenmeyer flasks were inoculated with two loopfuls of a 24 hour broth culture of **Ps. medicaginis, n. sp.** Five cubic centimeters were taken from each flask for titration every twenty-four hours for a period of ten days. This was diluted with 45 c.c. of distilled water in a porcelain evaporating dish and titrated cold with N/10 NaOH or N/10 HCl as the case required. Phenolphthalein was used as the indicator. An examination of Table No. 1 will show that in no instance has there been any acid produced, while on the other hand, after the third day, there has been a gradual production of alkali until after

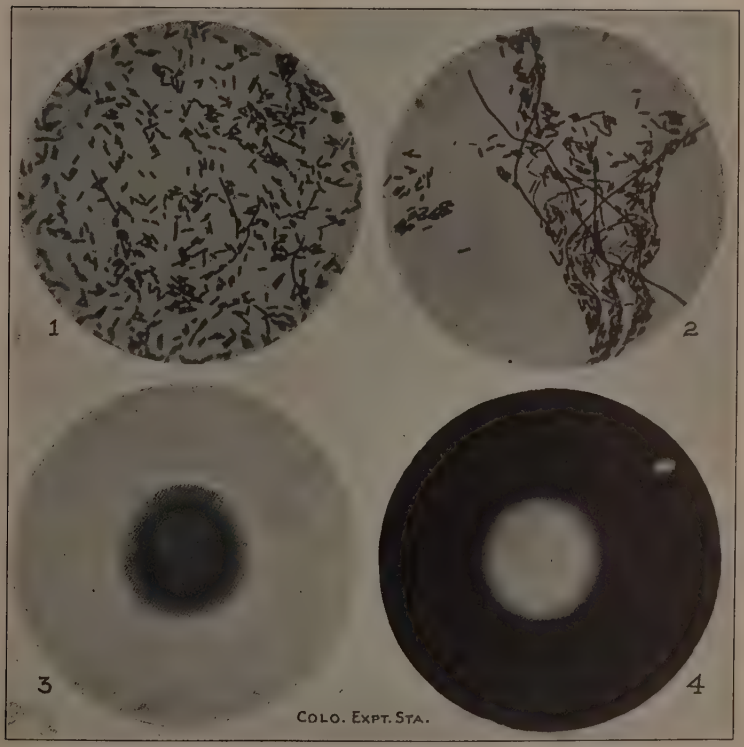

PLATE I.

ten days growth the cultures were decidedly alkaline. The dextrose broth fell from +10 to —3, the saccharose broth from +8 to —5, the lactose broth from +8 to —6, the maltose broth from +8 to —5, the glycerine broth from +8 to —4, the mannite broth from +8 to —7. The results of the daily titrations are given in Table No. 1.

TABLE NO. 1—PRODUCTION OF ACID AND ALKALI.

Sugar Free Broth plus 1%	Degree of Reaction After									
	No ds	1 d	2 ds	3 ds	4 ds	5 ds	6 ds	7 ds	8 ds	9 ds	10 ds
Dextrose	10	10	10	10	9	6	4	2	1	0	—3
Saccharose	8	8	8	8	8	6	3	1	0	—4	—5
Lactose	8	8	8	8	6	4	2	0	—1	—4	—5
Maltose	8	8	8	8	7	7	5	1	0	—4	—5
Glycerine	8	8	8	8	7	5	2	1	0	—3	—4
Mannite	8	8	8	8	7	4	2	1	—1	—5	—7

3. Production of Ammonia.

The production of ammonia has been determined in nutrient broth, Dunham's peptone solution, Jordan's asparagin solution and nitrate broth. 100 c.c. portions of nutrient broth and Dunham's solution were placed in 500 c.c. Erlenmeyer flasks, sterilized, and inoculated with a 48 hour agar culture. Similar portions of each of these media were kept as sterile controls. After ten days, both the cultures and the uninoculated checks were analyzed for ammonia by distillation with magnesium oxid. The distillates were collected in N/10 H_2SO_4 and subsequently titrated with N/10 NaOH. Ammonia was produced by the culture both in the nutrient broth and in the peptone solution, the larger amount being present in the former. The results are given in Table No. 2 below.

TABLE NO. 2—PRODUCTION OF AMMONIA.

Medium	Milligrams NH_3 in 100 c. c. of culture	Milligrams NH_3 in 100 c. c. uninoculated control	Milligrams NH_3 produced by the bacteria
Nutrient Broth	21.63318	18.39672	3.23646
Dunham's Solution	4.00279	2.81060	1.19219

Large quantities of ammonia were produced in the asparagin solution after ten days. This was easily demonstrated by adding one cubic centimeter of Nessler's solution to inoculated tubes of this medium.

No ammonia was produced in nitrate broth by the reduction of the nitrates.

4. Nitrates in Nitrate Broth.

Nitrates are not reduced. Tubes of nitrate broth inoculated with **Ps. medicaginis, n. sp.** were tested after five days and ten days for nitrites and ammonia, and both were found absent. A subsequent test for nitrates showed the original nitrate to be present as such.

5. Indol Production.

There is no indol produced in Dunham's peptone solution.

6. Relation to Acid and Alkali.

The organism exhibits much more latitude in the reaction of its food stuffs on the acid side of the neutral point than on

the alkaline, the limits of growth being from —4° to +32° Fuller's scale. The optimum reaction appears to be between +15 and +18. Growth is retarded by a neutral reaction, on the one side, and by +32 on the other, and is prevented entirely by —6 and +34.

To tubes containing exactly 5 c.c. of sterile broth, sufficient standard NaOH or HCl was added, with aseptic precautions, to give them reactions ranging from —40 to +40, each tube differing by 2° from the others, thus: —40°....—8°, —6°, —4°, —2°, 0°, +2°, +4°, +6°, +8°.....+40°. Six tubes were prepared for each reaction, one of which was titrated to verify the degree of acidity or alkalinity. Without further sterilization, these tubes were inoculated with two loopfuls of a 48 hour broth culture and allowed to develop at 28° C. We found by trial that if the broth was sterilized after the acid or alkali had been added, the reaction might change considerably, especially in the case of the alkali, due, presumably, to certain chemical combinations which took place between the NaOH and the broth constituents at the sterilizing temperature (95.5° C. Altitude 4,981 feet above sea level). This was borne out by the fact that if the medium was not sterilized after adding the NaOH, —6° was sufficient to inhibit growth, but if sterilized, broth reacting —10° before being heated was required to accomplish the same result.

Detailed results of the experiment are given in Tables Nos. 3 and 4.

TABLE NO. 3—RELATION TO ACID.

Degree of Acid	Growth Resulting After Given Number of Days									
	1 d.	2 d.	3 d.	4 d.	5 d.	6 d.	7 d.	8 d.	9 d.	10 d.
0	—	—	—	+	+	+	+	+	+	+
2	—	+	+	+	+	+	+	+	+	+
4	—	+	+	+	+	+	+	+	+	+
6	+	+	+	+	+	+	+	+	+	+
8	+	+	+	+	+	+	+	+	+	+
10	+	+	+	+	+	+	+	+	+	+
12	+	+	+	+	+	+	+	+	+	+
14	(+)	+	+	+	+	+	+	+	+	+
16	(+)	+	+	+	+	+	+	+	+	+
18	(+)	+	+	+	+	+	+	+	+	+
20	+	+	+	+	+	+	+	+	+	+
22	+	+	+	+	+	+	+	+	+	+
24	—	+	+	+	+	+	+	+	+	+
26	—	+	+	+	+	+	+	+	+	+
28	—	+	+	+	+	+	+	+	+	+
30	—	+	+	+	+	+	+	+	+	+
32	—	—	—	—	—	+	+	+	+	+
34	—	—	—	—	—	—	—	—	—	—
36	—	—	—	—	—	—	—	—	—	—
38	—	—	—	—	—	—	—	—	—	—

TABLE NO. 4—RELATION TO ALKALI.

Degree of Alkali	Growth Resulting After Given Number of Days									
	1 d.	2 d.	3 d.	4 d.	5 d.	6 d.	7 d.	8 d.	9 d.	10 d.
0	−	−	−	+	+	+	+	+	+	+
−2	−	−	−	−	+	+	+	+	+	+
−4	−	−	−	−	−	+	+	+	+	+
−6	−	−	−	−		−	−		−	−
−8	−	−	−	−	−	−	−	−	−	−
−10	−	−	−	−	−	−	−	−	−	−
−12	−	−	−	−	−	−	−		−	−
−14	−	−	−	−	−	−		−	−	−
−16	−	−	−	−	−	−	−	−	−	−
−18	−	−	−	−	−	−	−	−		−
−20	−	−	−	−	−	−	−	−	−	−
−22	−	−	−	−	−	−	−	−	−	−
−24	−	−	−	−	−	−	−	−	−	−
−26	−	−	−	−	−	−	−	−	−	−
−28	−	−	−	−	−	−	−	−	−	−
−30	−	−	−	−	−	−	−	−	−	−
−32	−	−	−	−	−	−	−	−	−	−
−34	−	−	−	−	−	−	−	−	−	−
−36	−	−	−	−	−	−	−	−	−	−
−38	−	−	−	−	−	−	−	−	−	−

(+) Best growth.

7. Optimum Reaction.

The optimum reaction for growth in bouillon is +15° to +18° Fuller's scale.

8. Vitality on Culture Media.

Vitality on culture media is only moderate. Transfers made from a stab culture in nutrient agar which was four months old failed to give any growth; however, growth has been obtained from cultures on agar which were six weeks old. No difficulty has been experienced in carrying the culture upon nutrient agar if it transferred as often as once in ten days.

9. Temperature Relations.

THERMAL DEATH-POINT.—The thermal death-point lies between 49° and 50° C. 10 c.c. portions of nutrient broth, +15 Fuller's scale, in thin walled test tubes of resistance glass, having a uniform diameter of 16 to 17 m.m., were inoculated with two loopfuls of a 24 hour broth culture grown at 28° C. As soon as inoculated, the tubes were plunged into water of the desired temperature up to the cotton plugs, and kept there for exactly ten minutes. In order to insure a uniform temperature, the water in the water bath in which the exposures were made, was kept in constant motion by a horizontal paddle attached to a stirring machine and operated by a water motor. The different temperatures were maintained by hand regulations with a Bunsen burner. At the end of the ten minutes exposure, the tubes were immediately cooled in cold water and subsequently allowed to develop at 28° C. Twelve tubes of broth were used for each temperature and determinations were made for each degree of temperature from 40° to 60° C. If turbidity appeared in any of the tubes within ten days, this was taken as an indication that the temperature to which the tubes were exposed was not fatal.

OPTIMUM TEMPERATURE.—The optimum temperature lies between 28° and 30° C.

37½° C., no growth occurs on nutrient agar, in nutrient broth or in the various sugar broths.

28° C., abundant growth on agar and moderate in broth after 48 hours.

20° C., moderate growth on agar and slight in broth after 48 hours.

10° C., slight growth on agar and none in broth in 48 hours.

6.5° C., slight growth on agar and none in broth in 48 hours; moderate growth on agar and slight in broth in 6 days.

10. Relation to Oxygen.

Ps. medicaginis, n. sp. appears to be an obligative aerobe. Stab cultures were made in glucose litmus gelatin and placed in an atmosphere of hydrogen in a Novy jar. No growth whatever took place in 120 days. Again, in our studies upon gas production from the different sugars, glycerine and mannite, we have observed that no growth occurred in the closed arm of the fermentation tubes and that there was a sharp line of demarcation between the growth in the open arm and the clear liquid in the closed arm. This would seem to point strongly toward the aerobic nature of the germ. The total absence of any deep growth in the gelatin stab serves to emphasize further this feature.

11. Effect of Dessication.

The organism is relatively resistant to drying, being able to withstand dessication for eleven days when spread on cover glasses and dried in sterile Petri dishes. A suspension of the 24 hour growth on agar was made in sterile water, and one loopful of this was spread over each of a number of one-half cover glasses, sterilized by flaming. These smears were placed in sterile Petri dishes at once and allowed to dry. Every twenty-four hours for a period of twenty-two days, two of these inoculated cover glasses were taken out and dropped into tubes of sterile broth; if growth resulted, this was taken as evidence that the germs had not been killed by drying. Detailed observations are given in Table No. 5 below.

TABLE NO. 5—EFFECT OF DESSICATION.

Number of Days Dried	Growth Resulting in Broth After Given Number of Days									
	1 d.	2 d.	3 d.	4 d.	5 d.	6 d.	7 d.	8 d.	9 d.	10 d.
1	0	0	+	+	+	+	+	+	+	+
2	0	0	+	+	+	+	+	+	+	+
3	0	0	+	+	+	+	+	+	+	+
4	0	0	+	+	+	+	+	+	+	+
5	0	0	0	0	+	+	+	+	+	+
6	0	0	0	0	0	0	0	0	0	0
7	0	0	+	+	+	+	+	+	+	+
8	0	0	0	+	+	+	+	+	+	+
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	+	+	+
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0
0	0	0	+	+	+	+	+	+	+	+

12. Relation to Freezing.

1/100 c.c. and 1/10,000 c.c. portions of a 24 hour broth culture grown at 28° C., were plated in nutrient agar as controls. This culture was then frozen in a mixture of snow and salt, and kept in this condition for 24 hours, at the end of which time it was thawed out by placing it in an incubator at 28° C. As soon as melted, dilution plates were made using the same amounts as before freezing. After four days, colony counts were made which showed the culture to have contained 470,000 germs per c.c. before freezing and 5,100 after freezing, or 98.9 % had been killed.

13. Relation to Light.

DIRECT SUNLIGHT.—Three tubes of liquefied agar were sown thinly with different amounts of a 24 hour broth culture and poured into sterile Petri dishes. As soon as the agar had solidified, one half of each plate was covered with one thickness of heavy, black, glazed paper. They were then placed on a bed of firmly packed snow in a large crystalizing dish and the whole was exposed for fifteen minutes to the bright sunshine of Fort Collins, Colorado (altitude 4,981 feet above sea level), Nov. 20, 1909, 11:30-11:45 A. M.

100 % of the germs were killed in the exposed portions of the plates, while 25, 9, and 5 colonies, respectively, developed in the protected parts.

DIFFUSED LIGHT.—Our cultures have been kept in diffused light in a culture room supplied with light from a north window, which was perhaps eight feet from the table on which the cultures were kept. We have never noticed any detrimental effect from this light upon either the vigor or the virulence of the cultures. Other cultures have been kept next to the window for a week at a time, and when subcultures were made from these, no difficulty has been experienced in getting good growths.

14. Production of Hydrogen Sulphide.

Nutrient broth in tubes was inoculated with a 48 hour agar culture, and at the same time narrow strips of filter paper, moistened with lead acetate, were suspended in the upper part of the tubes and held in place by the cotton plugs. These strips of paper were remoistened with lead acetate every twenty-four hours for a period of ten days but there was no blackening to indicate the production of hydrogen sulphide.

A second method of demonstrating H_2S was to make stab cultures in nutrient gelatin to which .5% of iron potassium tartrate had been added. If hydrogen sulphide had been produced, the line of puncture should have been marked by a well defined black line due to the formation of iron sulphide. Tubes of this medium inocualted with **Ps. medicaginis, n. sp.** failed to show the production of any H_2S.

15. Production of Ferments.

Determinations have been made for the presence of diastase, invertase, zymase, rennet, pepsin and glucase. Tests were made for these enzymes after five, seven and thirty days, and the only one which we have been able to demonstrate was invertase. A trace of this was evident on the seventh day, and was abundant at the end of thirty days. A 48 hour agar culture has been employed in all of the inoculations.

DIASTASE.—100 c.c. of sugar free beef broth containing.1% soluble starch were inoculated with the organism under study. After five, seven and thirty days, portions were removed from the flask with a sterile pipette and tested for starch with iodine

solution, and for maltose with Fehling's solution. Starch was present at all times, and at no time was there any reduction of the Fehling's solution; therefore no diastase was formed.

INVERTASE.—Saccharose broth, prepared by adding 1% of saccharose to sugar free broth, was used in the determination of invertase. 100 c.c. of this medium were inoculated and after five, seven and thirty days tests were made for invert sugar with Fehling's solution. There was no reduction at the end of five days, a slight one after seven days and at the end of thirty days, a good test for glucose was obtained from the inoculated flask, while the sterile control gave no reduction of the Fehling's solution; therefore invertase was formed.

ZYMASE.—Glucose broth, prepared by adding 1% of glucose to sugar free broth, was used in our study of zymase. Observations covering a period of thirty days failed to show at any time the evolution of CO_2 gas, or the presence of alcohol in the inoculated tubes, and consequently, we have concluded that there was no zymase produced.

RENNET.—Plain milk was employed as the medium in the study of rennet production. At no time during the thirty day period of examination, did the inoculated milk tubes show any evidence of curd formation, which fact has been interpreted as indicating the absence of rennet.

PEPSIN.—Plain milk and nutrient gelatin, contained in test tubes, were epmloyed as the media in the study of pepsin formation. Stab cultures were made in the gelatin and the milk was inoculated in the usual way. There was neither any liquefaction of the gelatin nor any digestion of the casein of the milk during the period of observation, which was sixty days for the gelatin and forty days for the milk.

GLUCASE.—Beer wort, and sugar free broth to which 1% of maltose was added, furnished the media for the study of glucase, but owing to the difficulty in distinguishing maltose from glucase when present in the same solution, no satisfactory conclusions could be reached regarding the presence of glucase, and hence concerning the production of glucase.

16. Crystals Formed.

No crystals have been observed to form in any of the media employed.

IV. PATHOGENICITY

1. Pathogenic to Animals.

Inasmuch as the organism does not grow at 37½° C. it has been considered unnecessary to carry on any animal inoculations.

2. Pathogenic to Plants.

Pathogenic for alfalfa **(Medicago sativa)**; not pathogenic under field conditions for sweet clover **(Melilotus alba)**, white clover **(Trifolium repens)**, or winter vetch **(Vicia sativa)**.

V. NUMERICAL CLASSIFICATION

According to the numerical system of recording the salient characters of an organism, **Ps. medicaginis, n. sp.** (Sackett) becomes Ps. 212.3332133.

MEDIA EMPLOYED.

The *nutrient broth, nutrient gelatin, nutrient agar* and *sugar free broth,* employed in this work, have been prepared according to the Standard Methods of Water Analysis (1). Reaction +15° Fuller's scale.

Sugar Broths.—These were prepared by adding one per cent of the different sugars, as well as glycerine and mannite, to sugar free broth.

Glycerine Agar.—Prepared by adding four to six per cent glycerine to nutrient agar.

Dunham's Solution.—

Distilled water	1000.0 c. c.
Witte's Peptone	10.0 grams
NaCl	5.0 grams

Nitrate Broth.—

Distilled water	1000.0 c. c.
Witte's Peptone	1.0 gram
KNO_8 (nitrite free)	.2 gram

Asparagin Solution.—(Jordan). (2)

Redistilled water	1000.0 c. c.
Asparagin	2 0 grams
$MgSO_4$	1.0 grams
K_2HPO_4	1.0 grams

(1) Supplement Journal Infect. Diseases, May, 1905, p. 104.
(2) Jordan. Bot. Gaz., 1899, 27, p. 9; Jour. Expt. Med., 1899, 4, p. 627.

Uschinsky's Solution.—(1)

Distilled water	1000.0 c. c.
Glycerine	30–40 grams
NaCl	5– 7 grams
$CaCl_2$	.1 grams
$MgSO_4$	.2–.4 grams
K_2HPO_4	2.–2.5 grams
Ammonium lactate	6 –7 grams
Sodium asparaginate	3 –4 grams

Cohn's Solution.—(2)

Distilled water	1000.0 c. c.
KH_2PO_4	5.0 grams
$MgSO_4$	6.0 grams
Ammonium tartrate	10.0 grams
KCl	.5 grams

Synthetic Agar, Low in Nitrogen.—

Distilled water	1000.0 c. c.
Cane sugar	50.0 grams
KH_2PO_4	1.0 gram
$MgSO_4$	.2 gram
Shredded agar	15.0 grams

Reaction +3° Fuller's scale.
(1) Cent. f. Bakt., Erste Abt., Bd. XIV., 1893, p. 316.
(2) DeBarry, p. 86, Vorles. u. Bact., 2 Auflage.

Potato.—Cylinders of raw potato were washed in running water over night, rinsed in a very dilute solution of NaOH, and sterilized in the autoclave for five minutes at 120° C.

Alfalfa Agar.—Prepared by adding 15 grams of finely shredded agar to 1,000 c.c. alfalfa infusion made by steeping 500 grams finely chopped green alfalfa in 1,000.0 c.c. tap water for one hour. Reaction not changed.

Litmus Milk.—Prepared by adding to plain milk one per cent of a solution of azolitmin made by dissolving 1 gram of azolitmin in 40 c.c. of distilled water and kept at 37.5° C. for 12 to 18 hours.

GREENHOUSE EXPERIMENTS.

The constant occurrence of characteristic white colonies, in such a large percentage of our plates, was sufficient to make us suspicious that the micro-organisms making up such colonies were the immediate cause of the disease. However, the crucial test of a pathogenic organism is its power to reproduce the given disease when introduced in pure culture into its normal host. Accordingly, we have fulfilled this requirement by making a large number of inoculations upon alfalfa plants under greenhouse conditions, and by this means we have been able to establish *Ps. medicaginis, n. sp.* beyond the remotest shade of possible doubt, as the unquestionable cause of the trouble. We have reproduced the infection in from five to seven days with practically its characteristic field symptoms, and we have been able to follow its progress through the different changes up to the blackening and complete destruction of the stem after six weeks.

In the plant inoculations, which are described below, we have employed three different germs. These are the only ones which we have met with in our isolations, and for convenience they are here referred to as "Yellow Colony," "Orange Colony" and "White Colony," the last, *Ps. medicaginis, n. sp.*, having been shown to be alone responsible for the disease.

Successful inoculations have been obtained by scarifying the epidermis of the stems with a sterile scalpel, and then immediately smearing the freshly exposed, moist surface with a 48 to 72 hour agar culture of the organism. Another method has been to prick the stem at intervals of about one centimeter with a needle previously dipped into the growth of a 48 to 72 hour agar streak. Again, we have rubbed the culture over the surface without any previous injury to the epidermis.

No precautions have been taken against the drying out of the inoculated areas other than to spray the plants once just after inoculation, and once a day thereafter for the next three days with sterile water. A water bottle with a fine rose nozzle has been used for this work. The spray would collect in large drops, and ultimately run down the stems, and in this way moisten the inoculated regions. This treatment together with the moist atmosphere of the greenhouse seemed adequate.

Plant Inoculations of June 3, 1909.

Cultures used were isolated June 1, 1909.

Pot No. 1.—The epidermis of each of four stems was scarified for a space of 10 cm. and smeared with a 48 hour agar culture of Ps. medi-

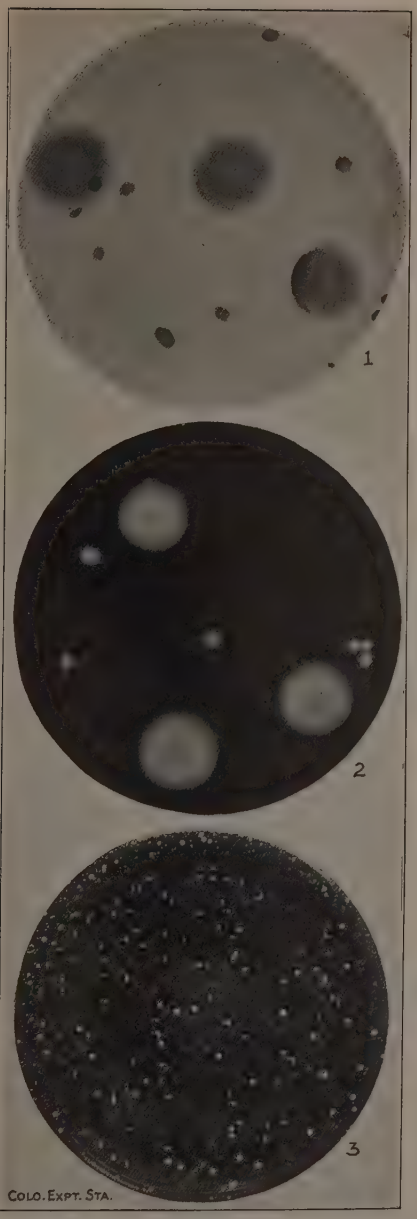

PLATE II.

ginis, n. sp. obtained from an infected stem. For comparison with inoculations not specially protected against dessication, this pot was covered with a bell jar, the opening in the top being stoppered with a cotton plug. Circulation of air was possible yet there was a moist, if not saturated, atmosphere surrounding the plant all the time. By June 18th., the scraped areas were blackened and a microscopic examination of this tissue showed the characteristic milky cloud and swarms of bacteria.

Pot No. 2.—Each of four stems was inoculated by ten needle pricks with a 48 hour agar culture of **Ps. medicaginis, n. sp.** This pot was also covered with a bell jar as described above. By June 18th, each needle prick showed a dark brown zone 1 mm. wide surrounding the point of infection. A microscopic examination of the tissue from this zone showed clouds of motile bacteria.

Pot No. 3.—Four stems were inoculated in the same manner as those of Pot No. 1, but they were not covered with a bell jar. The plant was sprayed with sterile water once a day for the first three days after inoculation. By June 18th., the stems were blackened and exhibited the characteristic phenomena under the microscope. The diseased condition of the stems was much more typical than in those which were covered with the bell jar.

Pot No. 4.—Four stems were inoculated in the same manner as those of Pot No. 2, but they were not covered with a bell jar. They were sprayed with sterile water once a day for the first three days after inoculation. On June 18th., there was a brown area surrounding each needle prick and a microscopic examination of the discolored tissue showed swarms of motile bacteria. The gross appearance of the diseased parts was more typical than in the plant covered with a bell jar.

Pot No. 5.—Four stems were scarified and inoculated with a 48 hour culture of **Ps. medicaginis, n. sp.** isolated from a diseased leaf. The plant was covered with a bell jar. The stems were blackened by June 18th., but they were not as typical as those which were left uncovered.

Pot No. 6.—Four stems were inoculated by needle pricks with a 48 hour culture of **Ps. medicaginis, n. sp.** isolated from a diseased leaf. The plant was covered with a bell jar. June 18th., the disease was evident from the blackened areas around each needle prick, but it was not as typical as in those stems which were not covered.

Pot No. 7.—Four stems were inoculated in the same manner as Pot No. 5, but were exposed to the air and sprayed with sterile water. By June 18th the disease was apparent by the blackened stems and a microscopic examination showed swarms of bacteria coming from the tissue and a milky cloud surrounding the whole; more typical than stems under bell jar.

Pot No. 8.—Four stems were inoculated in the same manner as Pot No. 6, but were exposed to air and sprayed with sterile water. June 18th. there were dark brown areas surrounding each puncture; very typical; microscopic examinations characteristic.

Plant Inoculations of June 7, 1909.

Cultures used were isolated June 1, 1909.

Pot No. 9.—Each of four stems was scarified and inoculated with a 48 hour culture from a yellow colony isolated from a black stem. By June 18th. the stem was slightly yellow and shiny but probably nothing more than the result of the scraping; nothing typical had developed; there was no sign of any growth of the germ and no evidence of any discolored or diseased tissue. Microscopic examination failed to show the presence of bacteria and consequently this germ was considered as not responsible for the trouble.

Pot No. 10.—Each of four stems was scarified and inoculated with a 48 hour culture from an orange colony, isolated from a diseased stem.

By June 18th. there was no change whatever in the inoculated stems, and on June 25th. they were in all respects the same as the uninoculated controls; therefore, this germ was eliminated as a possible cause of the disease.

Plant Inoculations of June 21, 1909.

The cultures used were isolated June 19, 1909.

Pot No. 11.—Five stems were inoculated by spreading a 48 hour agar culture of **Ps. medicaginis, n. sp.** upon the unbroken epidermis, the object being to determine whether stomatal infection could be produced in this way. After twenty days, isolated brownish spots appeared on the inoculated portions of all the plants, and after thirty days these brownish areas were black. A microscopic examination of the tissue showed the true infection.

The object of the following inoculations was to determine whether **Ps. medicaginis, n. sp.** was equally pathogenic when isolated from different stages in the progress of the disease.

Pot No. 12.—One stem was scarified and smeared while a second one was inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from a stem which had reached the brown stage of the disease. The infection developed in both stems after seven days and by August 1st. both were black.

Pot No 13.—One stem was scarified and smeared while a second one was inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from a stem in the earliest stage of the infection when it showed the light green, yellow, watery tissue. Both of the stems developed the disease in seven days and were black after five weeks.

Pot No. 14.—One stem was scarified and smeared while a second one was inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from a black stem in the advanced stage of the disease. Both stems developed the trouble in five to seven days and were black August 1.

Pot No. 15.—One stem was scarified and smeared while a second one was inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from what appeared to be a very recent stomatal infection on the stem; there was no indication of the epidermis being broken, and the disease occurred in isolated spots around the stomata. Both stems developed typical symptoms in five to seven days and were black by August 1st.

Pot No. 16.—One stem was scarified and smeared while a second one was inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from an advanced, black stomatal infection of the stem. Both stems developed the disease in five days, and the inoculated areas were black August 1st.

Pot No. 17.—One stem was scarified and smeared while another was inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from a single infected stoma of the stem. Both stems developed very good symptoms in four days and were black by August 1st.

Plant Inoculations of August 25, 1909.

Cultures used isolated June 1, 1909.

Pot No. 18.—Stem scraped over the whole internode and smeared with a culture of **Ps. medicaginis, n. sp.** isolated from a diseased stem: Sept. 3rd. inoculated area yellowish green color, watery and darker along the edge; Sept. 7th. dark brown; Sept. 30th. black.

Pot No. 19.—Stem scraped in patches and smeared with a culture of **Ps. medicaginis, n. sp.** isolated from a diseased stem. Sept. 3rd. inoculated spots plainly visible by the watery, yellowish green patches; Sept. 7th. spots dark brown; Sept. 30th. spots black.

Pot No. 20.—Stem inoculated by needle pricks with culture of **Ps. medicaginis, n. sp.** isolated from diseased stem. Sept. 3rd. watery areas for 1 to 2 mm. around each needle prick and yellowish; Sept. 7th. dark brown; Sept. 30th. black.

Pot No. 21.—Controls. One stem scarified with a sterile scalpel and a second pricked with a sterile needle. No change visible at any time in either stem.

Plant Inoculations of November 2, 1909.

Cultures used were isolated June 1, 1909.

Pot No. 22.—Three stems were scarified and smeared with a culture of **Ps. medicaginis, n. sp.** isolated from an infected stem. On Nov. 7th, two of them were watery, shiny and yellow, while a liquid had been oozing from one and had dried on the stem. The third stem showed almost no change from the check. By Nov. 18th. all of the scraped areas were dark, watery green and turning brown; by Nov. 20th, they were a dark brown; a microscopic examination on Nov. 23rd. showed a typical infection. (See colored plate.)

Pot No. 23.—Two stems were inoculated by needle pricks with a culture of **Ps. medicaginis, n. sp.** isolated from a diseased stem; Nov. 7th, yellowish, watery appearance around each one of the stabs; Nov. 18th, needle pricks all taking well; very well defined brownish green areas one to two mm. around each; infection spreads slowly; Nov. 20th. the diseased spots dark brown and slightly sunken; Nov. 23rd. an examination of the diseased tissue gave milky cloud in the mount and swarms of germs under the microscope. (See colored plate.)

Pot No. 24.—Stem inoculated by smearing culture of **Ps. medicaginis, n. sp.** upon the unbroken epidermis. The object, here, was to attempt to secure a successful infection through the stomata. Nov. 10th, two yellowish, watery spots developed on the part of the stem smeared; Nov. 18th. these spots were dark brown and by Nov. 24th. they were almost black. A subsequent microscopic examination showed a true bacterial infection.

In order to eliminate the germicidal action of the direct rays of the sun, the plants were shaded by one thickness of canvas, placed next to the glass roof.

In order to determine whether the infection was communicated to the plants through the roots, twelve pots were prepared with sick soil containing quantities of the diseased stems. Fifteen germinated alfalfa seeds, which had been sterilized previously in a 1-500 mercuric chloride solution, were planted in each of the above pots. A good, vigorous stand was obtained. The possibility of frozen stems was eliminated by growing the alfalfa in the greenhouse and the danger from dust infection was reduced to a minimum by keeping the surface soil in the pots moist. These plants are now sixteen months old and up to the present time not a single stem in any of the twelve pots has shown any sign of the disease. From these results, we can say with a reasonable degree of certainty, that the disease is not, primarily, a root trouble, and if the roots do become diseased, the infection must start from the crown and work downward.

SUMMARY OF GREENHOUSE EXPERIMENTS.

From these experiments it will be seen, first, that we have been able to produce the disease successfully in 100 per cent of the

plants inoculated with pure cultures of *Ps. medicaginis, n. sp.*; second, that cultures of this organism produce identically the same symptoms irrespective of their origin, i. e., whether they were originally isolated from stem, leaf or exudate; third, that it has been possible to produce the disease by introducing the germs through needle pricks and by smearing them upon scarified areas, as well as by spreading them upon the unbroken epidermis; however, inoculations by the last method develop more slowly and are not as typical of field lesions; fourth, that after cultivation upon nutrient agar for five months, *Ps. medicaginis, n. sp.* seems to have retained its initial virulence practically undiminished; fifth, that neither of the other two cultures which have been found associated with the trouble are able to produce the disease; sixth, that the infection is not communicated to the plants through the roots.

FIELD EXPERIMENTS.

Inasmuch as the disease seems to be directly tracable to soil infection, and consequently may be considered a soil trouble, the only practical method of controling it is by the introduction of resistant varieties. To this end we have planted twenty-six varieties of alfalfa on sick land with the hope of obtaining one or more blight resistant strains. The seed for this work was procured from the United States Department of Agriculture through Mr. W. J. Brand, and planted April 16 and 17, 1907. The ground upon which the plats are located is owned by Hon. J. L. Chatfield, and had been in alfalfa a number of years, was plowed in the spring of 1905 and planted to oats and potatoes; in 1906 again planted to oats and produced 100 bushels per acre. The rows of the plot are about fifteen rods long and run from east to west. Two rows of each variety were planted through the plot, then the series was repeated in the same order but only one row of a kind was used. The variety designated as Gypsum No. 1 was grown from cuttings which were taken from land that had been in alfalfa, and was plowed up because of the prevalence of the disease, and planted in oats. These plants were very vigorous at the time the cuttings were made. This part of the work was begun by Professor Paddock over two years ago.

The following is a list of the varieties which we have used in our field tests.

No. 9451, Sairam.
No. 11275, first quality commercial.
No. 12398, from Colorado.
No. 12409, Utah, non-irrigated.
No. 12671, from Kansas.
No. 12702, from Sherman, Texas.
No. 12747, from Billings, Mont.
No. 12748, from Germany.
No. 12784, Utah, irrigated.

No. 12801, from Texas Panhandle.
No. 12816, from Chinook, Mont.
No. 12820, from Nebraska.
No. 12846, from Kebilli Oasis, Tunis.
No. 13291, from New York.
No. 13259, from Nebraska.
No. 13857, from Simbirsk, Russia.
No. 17698, from Chinook, Mont.
No. 18751, from Turkestan.
No. 19508, from Kansas.
No. P. L. H. 3251, grown in South Dakota, from Baltic seed.
No. P. L. H. 3252, also grown in South Dakota.
No. 9322, from Touggourt.
No. 12694, from Provence, France.
No. 9453, from Bokhara.
No. 13437, from Arizona.
No. 1, Gypsum, Colorado, from cuttings.

A very satisfactory stand was secured with all varieties except No. 12,846 and No. 9,322. When the plants were one year old, they were examined very carefully for the presence of the disease with the result that all varieties but one, P. L. H. 3,251, were affected to a greater or less degree. While not all of the plants in each variety were suffering, some from each, with the exception of the one mentioned above, were diseased. Table No. 6, below, gives the results of these observations which were made June 20, 1908.

TABLE NO. 6

Showing Condition of the Different Varieties of Alfalfa When One Year Old. June 20, 1908.

Variety	Stand	Vigor	Prevalence of Disease	Size of Plants
9451	Fair	Fair	Present	Medium and small
11275	Good	Good	Present	Variable
12398	Fair	Fair	"	Variable
12409	Good	Good	"	Large
12671	Fair	Good	"	Variable
12702	"	Fair	"	Variable
12747	"	Good	"	Large
12748	"	Very good	"	Large
12801	"	Fair	"	Small
12816	"	Good	"	Variable
12820	"	Good	"	Variable
12846	Very poor	Very poor	"	Almost no plants
13291	Poor	Fair	"	Large
13259	Fair	Fair	"	Small
13857	Poor	Good	"	Large, varieties mixed
17698	Very good	Good	"	Low and large
18751	Good	Good	"	Variable
19508	"	Fair	"	Small
P. L. H. 3251	"	Very good	Absent	Large
P. L. H. 3252	Fair	Fair	Present	Small
12694	"	Poor	"	Frost bitten, varieties mixed
9453	"	Fair	"	Large spreading
13437	Poor	"	"	Small
12784	Fair	"	"	Variable
9322	.....	.....	.....	No plants
Gypsum 1	Very good	Very good	Present	Small

Similar observations, made June 11, 1909, when the plants were two years old, showed that all varieties were affected, including P. L. H. No. 3,251, which had promised immunity the previous season. At this time of the year, the alfalfa was from ten to twenty inches high; the majority of it had a good color, and while the blight was present in all varieties, it was not abundant enough to do any serious damage to the crop. Only a few stems of each plant were suffering and only the lower internodes of these. Such stems had the characteristic watery, yellow green color, very little blackening having occurred up to this time. Occasionally plants were found on which the attack had been so acute that they were entirely destroyed. Their location was marked only by patches of dwarfed, shriveled stems, now dried and prostrate. Four of the twenty-six varieties were noticibly freer from the infection than the rest, namely, No. 12,398, No. 12,671, No. 12,784, and P. L. H. 3,251. It is a matter of considerable practical interest, that the first three of these are from seed which we may consider as home grown; the first is from Colorado, the second, Kansas; the third, Utah. If we are so fortunate as to find high resistance in plants from local seed, the question of obtaining resistant varieties will be much more easily solved than if we are compelled to breed up a strain from foreign seed. Table No. 7 gives the detailed observations on the variety plats, made June 11, 1909.

TABLE NO. 7

Showing Condition of the Different Varieties of Alfalfa when Two Years Old. June 11, 1909.

Variety	Vigor	Prevalence of the Disease
9451.....	Fair	Present
11275.....	Fair	Present
12398.....	Good	Present, but not serious
12409.....	Fair	Present
12671.....	Good	Present, but not serious
12702.....	Good	Present
12747.....	Good	Present
12748.....	Fair	Present
12784	Good	Present, but not serious
12801.....	Poor	Present
12816.....	Fair	Present
12820.....	Good	Present
12846.....	No plants	No plants
13291.....	Fair	" "
13259.....	Fair	" "
13857.....	Poor	" "
17698.....	Good	" "
18751.....	Fair	" "
19508	Good	" "
3251.	Very good	Present, but not serious
3252.....	Fair	Present
9322.....	No plants	No plants
12694.	Very good	Present, but not serious
9453.....	Poor	Present
13437.....	Fair	Present, but not serious
GypsumNo.1	Good	Present, but not serious

We shall continue this part of the investigation with the same, as well as additional varieties, since the only practical way of testing out the disease resistance of these different kinds of alfalfa is to grow them under actual field conditions on infected soil, where natural agents are at work. We shall introduce, also, legumes other than alfalfa, in order to determine the susceptibility of these to the disease, so that we may be in a position to recommend other crops as substitutes where the land is so badly infected as to make profitable alfalfa growing no longer possible.

PREVENTION AND TREATMENT.

Where the areas under cultivation reach such tremendous proportions as the alfalfa fields on the mountain ranches, all schemes for soil sterilization are obviously impracticable at the outset. The same may be said of the use of germicides to be applied to the plants either in the form of sprays or otherwise, for even though some such means should be discovered by which the infection could be prevented, the cost would undoubtedly make it prohibitive. Obviously, then, as stated before, the only practical way of combating and controlling the blight is by the introduction of resistant varieties. What is being done in this direction has been mentioned before.

Our field observations during the past year seem to indicate that immunity to the disease is closely related to resistance to late spring freezing. On the one hand, those plants which were severely injured by the late spring frost were, without exception, the first to show the disease and were the worst infected later in the season; on the other hand, those varieties which grew from hardy stock and which suffered only slightly from the frost, were more nearly free from the blight. This coming year we shall endeavor to determine whether the relation between disease resistance and frost resistance is a constant one, and if it proves to be such, then we shall attempt to stamp out the trouble by securing frost resistant varieties.

In the meantime, we recommend, as a means of control, that the frosted alfalfa be clipped as soon as one is reasonably certain that there is no more danger from frost. By this means, the frost split stems, in which the disease appears to originate, will be gotten rid of, thus affording an opportunity for the early growth of a new cutting. Prof. P. K. Blinn, who has charge of the Experiment Station work at Rocky Ford, informs the writer that this practice of early clipping to remove the frost bitten shoots, which retard growth, is rapidly growing in favor among the farmers in his locality.

ACKNOWLEDGMENT.

The writer wishes to thank Prof. B. O. Longyear and Miss M. A. Palmer for the preparation of the colored plate.

EXPLANATION OF PLATES.

PLATE I.—Fig. 1, Ps. medicaginis, n. sp.; 24 hour agar culture stained with aqueous fuchsin; original x 1,000, reduced by engraver 6:5.

Fig. 2, Ps. medicaginis, n. sp.; 48 hour agar culture stained with aqueous fuchsin to show the formation of filaments; original x 1,000, reduced by engarver 6:5.

Fig. 3, Ps. medicaginis, n. sp.; surface agar colony 7 days old, photographed by transmitted light to show concentric rings of growth; original x 20, reduced by engraver 6:5.

Fig. 4, Ps. medicaginis, n. sp.; surface agar colony 7 days old, photographed by reflected light; original x 20, reduced by engraver 6:5.

PLATE II.—Fig. 1, Ps. medicaginis, n. sp.; agar colonies 7 days old showing deep and surface colonies by transmitted light; original x 20, reduced by engraver 3:2.

Fig. 2, Ps. medicaginis, n. sp.; agar colonies 7 days old showing deep and surface colonies by reflected light; original x 20, reduced by engraver 3:2.

Fig. 3, Petri dish showing pure culture of Ps. medicaginis colonies 2/3 natural size; original x 1, reduced by engraver 3:2.

PLATE III.—Fig. 1, Alfalfa stem, inoculated by smearing the freshly scraped stem with a 48 hour agar culture of Ps. medicaginis, x 2; 40 days after inoculation.

Fig. 2, Diseased alfalfa stem showing the yellowish, olive green color, characteristic in the early stages, x 2. Field specimen, natural inoculation.

Fig. 3, Diseased alfalfa stem showing the blackened condition in the late stages of the blight, x 2. Field specimen, natural inoculation.

Fig. 4, Alfalfa stem, inoculated with a 48 hour agar culture of Ps. medicaginis by means of needle pricks, x 2; 15 days after inoculation.

Fig. 5, Alfalfa leaf showing diseased, yellow areas, apparently of water pore or stomatal infection, x 2. Field specimen, natural inoculation.

NOTE.—Figs. 1 and 2, Plate I, were made by the writer with a Leitz Photomicrographic apparatus in connection with the Leitz microscope, 1/12 oil immersion objective, eyepiece I; Welsbach gas light; Cramer's Medium Isochromatic Plates. Figs. 3 and 4, Plate I, and Figs. 1 and 2, Plate II, were made by the writer with the Leitz Photomicrographic apparatus in connection with a Leitz Microsummar, 35 mm., f:4, 5. Plate III. was prepared by Miss M. A. Palmer and Prof. B. O. Longyear from fresh material.

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A NEW ALFALFA DISEASE

STEM BLIGHT

(An Abbreviated Edition of Bulletin 158)

BY

WALTER G. SACKETT

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STEM BLIGHT

*A New Bacterial Disease of Alfalfa**

By WALTER G. SACKETT.

HISTORY AND DISTRIBUTION.

In May of 1904, Hon. J. L. Chatfield, who resides at Gypsum, Eagle County, Colorado, observed that while the stand of alfalfa on his ranch was good, much of it was shorter than it should be at that time of the year, and that here and there plants were dying. He reported this condition to the Experiment Station at Fort Collins, and in response to his request, Professor Paddock and Professor Gillette visited his fields. They examined a number of plants, but they were unable to give any decisive answer as to the exact cause. Occasionally, worms were found in the crowns and in the roots, and by splitting the latter lengthwise, numerous dark streaks could be traced through the tissue. A few crowns were blackened, as well as some of the stems, but this discoloration was looked upon as due, possibly, to insect work, although no specific insects could be found at that time.

The following year, there was practically none of the trouble to be seen in the whole valley, which has an area of at least five thousand acres, more than one half of which is in alfalfa.

The next year, however, 1906, the conditions were worse than ever before and the universal complaint among the farmers was that there was "something wrong with the alfalfa." Professor Paddock again visited Gypsum, and at this time the blackened stems were very abundant and much more conspicuous than when he was there before. He brought back specimens of this material to the college and a microscopic examination satisfied him that, in all probability, the trouble was of bacterial origin. As a result of these findings, in November, 1906, Professor Paddock (1) called attention to a new alfalfa disease occurring in certain parts of Colorado, which was different from any previously described malady and which, from all appearances, was not related to either leaf spot or mildew.

The disease has spread with increasing severity until at the present time it is a very difficult matter to find one acre of alfalfa land in the whole valley which is entirely free from the trouble. The loss in tonnage for the first cutting is estimated at eighty per cent, or the crop is only one-fifth of what it was in former years. The disease became so serious in 1907 that it was thought advis-

* This is an abbreviated edition of Bulletin No. 158, entitled A Bacterial Disease of Alfalfa. The former includes detailed description of the causal bacterium and inoculation experiments. Bulletin No. 158 will be sent on request.

(1) Press Bulletin No. 28, Colo. Exp. Sta.

able to make the study of this malady a theme for special research. Accordingly, May 1, 1908, the writer began an intensive investigation of the trouble and during the past year has been occupied with laboratory, greenhouse and field experiments bearing upon the cause and possible remedies for the disease. The results of this work are given in the pages which follow.

DISTRIBUTION.

Within the state of Colorado, the disease occurs generally throughout the Gypsum Valley in Eagle county, to a somewhat less extent in Garfield county, and at Rocky Ford in the Arkansas Valley. Prof. W. Paddock has noted it in the Plateau Valley, Mesa county, and between Hotchkiss and Paonia in Delta county.

So far as our present knowledge goes, it has not been seen in the San Luis Valley, or in the Boulder, Longmont, Loveland, Fort Collins and Greeley districts.

In our neighboring states, what appears to be a similar bacterial disease has been observed by Professor Northrop in Utah, by Professor Wooten in New Mexico, by Professor Wilcox in Nebraska, and by Professor Roberts in Kansas. Its occurrence is reported as negative by Professor Nelson for Wyoming, by Professor Kennedy for Nevada, by Professor Lewis for Oklahoma, and by Professor Ball for Texas.

DESCRIPTION OF THE DISEASE.

When a field suffering with this bacterial trouble is viewed as a whole, about the only comment which could be made is that the growth is short and the alfalfa is a little off color. The rich, dark green color in the leaves is absent and the juicy, succulent appearance of the stem, so characteristic of a thrifty stand, is wanting. The plants tend to grow more spindling; the leaves often appear dwarfed, narrow, light green and have a tendency all along the stem and in the growing tip to remain partly closed just as they do in cold or dry weather.

The disease is primarily a stem infection and it is here that we find the most valuable characters for diagnosis. In the earliest stages, the stem has a watery, semi-transparent, yellowish to olive green appearance along one side. This extends down the stem from below the point of attachment of a leaf for one to three internodes. Again, on another side of the stem, the infection may cover two or three different internodes or parts of the same ones. Most commonly the first three to five internodes are the worst infected. Such stems are usually healthy and normal below the ground. Soon after they take on this dark, olive green, watery appearance, there oozes out from the diseased tissue a thick, clear, viscid liquid which spreads over the stem and collects here and there in little bead-like

droplets. This exudate dries in a short time with a glistening finish, and gives the stem very much the appearance of having been varnished, and where the liquid has collected in little amber colored scales and has hardened, it looks as if the varnish had run and dried. Stems in this condition have a dry, slightly rough feel to the touch. The exudate also dries uniformly over the surface or just beneath it, and there produces a dark brown, resinous surface which blackens with age. Such stems are very brittle and easily broken, which fact makes it almost impossible to handle the crop without an immense amount of shattering.

If the epidermis is scraped from an infected stem, the tissue underneath has the same yellowish, watery appearance. This pathological condition extends to the center of the stem and if it is split lengthwise, the interior cavity presents a brownish, mealy aspect. Such stems will collapse much more readily when pressed between the fingers than healthy ones. A shoot in this condition is virtually girdled; its circulation is impaired and its food supply is practically cut off as is evident from the poor growth it makes. Some stems remain in this inactive state and struggle along until the mowing machine puts an end to their existence; others turn black, shrivel and die six weeks before time for the first cutting. During the past season, the disease appeared about May 15th, and up until June 10, twenty-six days later, there were no blackened stems to be found. During this period, the trouble was manifested by the characteristic yellowish green, watery look.

The leaves attached to the diseased part of the stem usually show a watery, pale yellow color at the base, along the mid rib of the leaflets, and especially in the tiny petioles. Those on the parts of the stem which are blackened are always dried up, yellow and extremely brittle. The stipules at the base of the petioles are yellow and brittle and usually show the disease before their corresponding leaves.

Sometimes the leaves exhibit the infection independently of the stem. In this case the petioles become watery, pale yellow and droop. The malady may be confined to the petiole and base of the leaflet or it may involve the whole of the blade. Occasionally leaves are found where the inoculation has been made, apparently, in the margin of the leaflet, and the infection has proceeded toward the middle. In such instances, the tender tissue has a watery look, as if it had been bruised. These leaf infections have been observed to occur a little earlier than the stem troubles, although it may be merely a matter of being able to detect the pathological condition there first.

One year old plants may exhibit blackened areas in the crown, and black streaks which run down into the tap root. As the plant

grows older, this blackening increases until the whole crown becomes involved and either the crown buds are destroyed or the root is no longer able to perform its functions, and the plant dies.

So far as our present observations go, the disease appears to run its course with the first cutting, and those plants which have sufficient vitality, throw out a good growth for the second and third cuttings. Strange as it may seem, there is little or no trace of the blight during the remainder of the season, but in the following spring, a renewed outbreak may be looked for. The severity of the attack seems to vary from season to season. As has been noted before, the trouble was moderate in 1904; in 1905 it was practically unseen; in 1906 and 1907 it was extremely bad; in 1908 the attack was mild and during the past year there was but little to be found. This season the crop was the best that has been harvested for four years. This variation in the degree of the attack would seem to indicate that there may be some relation between the prevalence of the disease and the weather conditions, especially late frosts and late freezing, intermingled with warm, pleasant days as compared with a late, cold spring. Not many plants are killed the first year, but they begin to die after the blight has been prevalent more than one season, and after three or four years so many of them may be missing that the stand is practically worthless.

CAUSE OF THE DISEASE.

If a small piece of the yellowish green, watery tissue from a diseased plant, it matters not whether it be stem or leaf, is placed in a drop of clean water on a glass slide, there will appear on all sides of it, after half a minute, a dense, milky cloud, which can be seen readily with the naked eye, and which slowly diffuses out into the drop. When this preparation is examined under the low power of the microscope (Leitz Objective No. 3, Eye Piece IV.) this milky zone easily resolves itself into swarms of bacteria, which under the high power (Leitz Objective No. 7, Eye Piece IV.) can be distinguished as actively motile rods, relatively short and thick, with rounded ends and occurring for the most part singly and in twos.

If the surface tissue is removed and a portion of the deeper layers is examined, identically the same results will be obtained. If a fragment of the dried exudate is likewise placed in a drop of water, the whole gradually disintegrates and becomes a milky cloud, which under the microscope is a mass of motile bacteria.

Out of twenty-one infected stems examined and plated at different stages of the disease, thirteen gave pure cultures of this colony in the Petri dishes. In seventeen plates, it was the dominant colony. Platings from five different leaves gave pure cultures in three cases and in four out of five the above colony was the most

abundant. In other words, pure cultures were obtained in 62 per cent of the original isolations and in 81 per cent this white colony was dominant. In two out of twenty-six isolations or in seven per cent, it was absent. Plates made from the moist or freshly dried exudate, as a rule, gave pure cultures of the same organism.

Inoculations have been made upon alfalfa plants, grown under greenhouse conditions, with the three different cultures which have been isolated during this investigation, namely, the characteristic white one, the yellow and the orange, and the only one which has produced typical symptoms of the disease, in fact the only one which has produced any pathological condition whatever, is the dominant white colony referred to so frequently above. Cultures obtained from stem, leaf, petiole, or exudate, were equally pathogenic.

In order to establish further the fact, that this germ was the unmistakable cause of the trouble, an alfalfa plant was inoculated June 7, 1909 with our present stock culture of the causal organism, to which the name *Pseudomonas medicaginis*, n. sp. has been given, which was isolated from an infected stem May 27, 1909. By June 19, typical symptoms had developed, and plates were made from the yellowish green, watery tissue. On June 21, the Petri dishes showed a pure culture of the same white colony and the organism was reisolated on an agar slant. When compared with the original culture, the recovered organism was identical both in the hanging drop and when stained with aqueous fuchsin. The reisolated culture was again inoculated, June 25, by needle pricks into three different stems, and all of the inoculations gave positive results: the needle pricks showed a yellow, watery zone around the point of infection after nine days, and later turned black. When material from these diseased areas was examined microscopically, August 16, the same milky cloud appeared in the mount as has been described for field material, and swarms of motile rods were visible.

In all, one hundred and two inoculations have been made with this culture, introduced either by scraping the stem or by needle pricks, and positive results have been secured with one hundred per cent of the infections. Control inoculations with a sterile needle have been carried along with all of the experiments, and in no case have any of the check plants developed symptoms of the disease.

METHOD OF INFECTION.

In an effort to secure a satisfactory explanation of the method of infection, the writer spent over a month in the field where the disease is most prevalent. As a result of the daily observations and the gross and microscopic examination of more than three hundred plants, collected at all stages of the disease, before it made its appearance and until it was flourishing, he believes

the following to be the most tenable and satisfactory solution of the question.

This phase of the investigation was carried on at Gypsum, Colorado, where our first observations were taken May 4, 1909; this was early in the spring for this locality and altitude (over 6,000 feet above sea level). The season was considered cold and backward, and a moderately heavy snow had fallen one week before: traces of this were still to be seen in the valleys, and the surrounding hills and mountains were heavily covered.

The alfalfa was just beginning to grow, the average height in the diseased fields being from 1½ to 2 inches. Most of the plants had a yellowish green color due, presumably, to the cold. An examination of the young, succulent shoots showed that the epidermis of practically every one of them was wrinkled just below the point of attachment of the first four or five leaves, and often this wrinkling extended half way to the next leaf below. The epidermis was loose from the tissue beneath and appeared to be too large for the stem. When this was peeled off, the underlying tissue had a yellowish, green color much like the diseased plants, but a microscopic examination of such material failed to show any micro-organisms present. In those parts of the stem where this wrinkling was absent, the tissue beneath the epidermis was not yellow, but a whitish green. In many plants, the loosened epidermis had the appearance of partially collapsed blisters, while around and underneath these blisters the tissue seemed darker than normal and watery, with a suggestion of its having been frozen. Numerous lenticular breaks occurred in the epidermis of some stems. These might have been due to insect work although rather early in the season for this. Occasionally stems were found where the wrinkled epidermis had split open for a distance of one centimeter, exposing the moist pyrenchyma beneath.

Ten days later, May 14, the epidermis of practically every stem in the field was split wide open from node to node over the first six internodes, the third to the fifth internodes being the most common. This splitting appeared to have begun with the wrinkled epidermis mentioned above, and had extended the whole length of the internode thereby exposing the succulent, moist tissue beneath to infection. It is the concensus of opinion of those who have observed this phenomenon, that both the breaking away of the epidermis from the underlying tissue and the wrinkling and subsequent splitting are caused by freezing. A similar trouble ascribed to freezing has been observed in cherry trees and less frequently in the apple. Here the bark cracks and later splits open, exposing the green wood beneath just as in the alfalfa stems.

Anyone who has ever lived in Colorado is familiar with the

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soil carrying capacity of our winds, and with this in mind, it is easy to understand how germ laden soil might be blown into these cracks, where it would adhere to the moist, exposed surface, and bring about a fatal inoculation. As a matter of fact, soil was always found adhering to these surfaces, and, already, typical cases of the disease were developing. A microscopic examination of the tissues from the injured areas usually showed the germs to be present in great numbers, while ten days previous, that is before the splitting had occurred, there was no indication of any infection. Invariably, the disease appeared first and was worst on those parts of the stem where the epidermis had split and where soil had been caught in the open wound. A striking example of this was seen in an alfalfa field adjacent to a field which had been cultivated recently and sown to oats. The oat field was on the windward side, and with every gust, quantities of fine soil were carried over into the alfalfa. All along this side of the field, there was an aggravated attack of the disease, extending twenty to thirty feet into the alfalfa and the whole length of the field. Every plant was gray with soil and it is only reasonable to suppose that the disease was more severe here than in the more remote parts of the field because of the heavier soil inoculation.

This explanation satisfies one of the most difficult questions which has arisen in connection with the problem, namely, why does the first cutting, alone, suffer from the attack? There are never any frosts after the first crop is out of the way, and consequently there are no split stems in which to start the infection.

In a preliminary report (1), the writer has suggested that possibly the constant tramping of cattle and horses, pastured on the alfalfa fields during the winter, might have split open the crowns and bruised the young, tender shoots so that during the first irrigation, soil containing the disease germs was washed into the injured tissue and started the trouble on the first cutting. Our observations during the past season do not warrant such a conclusion in the majority of cases at least, since, in the first place, the disease was active at least two weeks before the first irrigation, and in the second place, our experimental plats, to which stock had no access, suffered just as severely as the fields which were pastured.

Not infrequently, we find the disease at work on stems where there has been no apparent previous injury to the epidermis; sometimes this assumes the form of a continuous, unbroken infection of the whole internode, and again it occurs as separate, punctiform lesions giving the stem a speckled appearance. This last condition would seem to indicate an infection through the stomata, and inasmuch as we have been able to secure successful inoculations in the

(1) Bulletin 138, Colo. Exp. Sta., Jan. 1909.

greenhouse by applying the culture to the unbroken epidermis, it is altogether possible that stomatal infections take place under field conditions. The leaflets often exhibit yellowish, watery areas along the margin and the larger veins when there is no evidence of the trouble in any other part of the plant; again, the tiny petioles succumb to the disease independently of either the stem or the attached leaflets. Water pore and stomatal infection similar to that described for the black rot of cabbage may explain these cases.

There are doubtless other ways in which infection can take place, but the methods described above, especially the inoculation through the split epidermis, seem to be the most common. It is possible that added observations of another season will give us more light upon this point and so rather than draw any final conclusion as to the *one way* in which inoculation takes place in the field, we prefer to leave the question open.

GREENHOUSE EXPERIMENTS.

The constant occurrence of characteristic white colonies, in such a large percentage of our plates, was sufficient to make us suspicious that the micro-organisms making up such colonies were the immediate cause of the disease. However, the crucial test of a pathogenic organism is its power to reproduce the given disease when introduced in pure culture into its normal host. Accordingly, we have fulfilled this requirement by making a large number of inoculations upon alfalfa plants under greenhouse conditions, and by this means we have been able to establish *Ps. medicaginis, n. sp.* beyond the remotest shade of possible doubt, as the unquestionable cause of the trouble. We have reproduced the infection in from five to seven days with practically its characteristic field symptoms, and we have been able to follow its progress through the different changes up to the blackening and complete destruction of the stem after six weeks.

In order to determine whether the infection was communicated to the plants through the roots, twelve pots were prepared with sick soil containing quantities of the diseased stems. Fifteen germinated alfalfa seeds, which had been sterilized previously in a 1-500 mercuric chloride solution, were planted in each of the above pots. A good, vigorous stand was obtained. The possibility of frozen stems was eliminated by growing the alfalfa in the greenhouse and the danger from dust infection was reduced to a minimum by keeping the surface soil in the pots moist. These plants are now sixteen months old and up to the present time not a single stem in any of the twelve pots has shown any sign of the disease. From these results, we can say with a reasonable degree of certainty, that the disease is not, primarily, a root trouble, and if the roots do become

diseased. the infection must start from the crown and work downward.

FIELD EXPERIMENTS.

Inasmuch as the disease seems to be directly tracable to soil infection, and consequently may be considered a soil trouble, the only practical method of controling it is by the introduction of resistant varieties. To this end we have planted twenty-six varieties of alfalfa on sick land with the hope of obtaining one or more blight resistant strains. The seed for this work was procured from the United States Department of Agriculture through Mr. W. J. Brand, and planted April 16 and 17, 1907. The ground upon which the plats are located is owned by Hon. J. L. Chatfield, and had been in alfalfa a number of years, was plowed in the spring of 1905 and planted to oats and potatoes; in 1906 again planted to oats and produced 100 bushels per acre. The rows of the plot are about fifteen rods long and run from east to west. Two rows of each variety were planted through the plot, then the series was repeated in the same order but only one row of a kind was used. The variety designated as Gypsum No. 1 was grown from cuttings which were taken from land that had been in alfalfa, and was plowed up because of the prevalence of the disease, and planted in oats. These plants were very vigorous at the time the cuttings were made. This part of the work was begun by Professor Paddock over two years ago.

The following is a list of the varieties which we have used in our field tests.

No. 9451, Sairam.
No. 11275, first quality commercial.
No. 12398, from Colorado.
No. 12409, Utah, non-irrigated.
No. 12671, from Kansas.
No. 12702, from Sherman, Texas.
No. 12747, from Billings, Mont.
No. 12748, from Germany.
No. 12784, Utah, irrigated.
No. 12801, from Texas Panhandle.
No. 12816, from Chinook, Mont.
No. 12820, from Nebraska.
No. 12846, from Kebilli Oasis, Tunis.
No. 13291, from New York.
No. 13259, from Nebraska.
No. 13857, from Simbirsk, Russia.
No. 17698, from Chinook, Mont.
No. 18751, from Turkestan.
No. 19508, from Kansas.
No. P. L. H. 3251, grown in South Dakota, from Baltic seed.
No. P. L. H. 3252, also grown in South Dakota.
No. 9322, from Touggourt.
No. 12694, from Provence, France.
No. 9453, from Bokhara.
No. 13437, from Arizona.
No. 1, Gypsum, Colorado, from cuttings.

A very satisfactory stand was secured with all varieties except No. 12,846 and No. 9,322. When the plants were one year old, they were examined very carefully for the presence of the disease with the result that all varieties but one, P. L. H. 3,251, were affected to a greater or less degree. While not all of the plants in each variety were suffering, some from each, with the exception of the one mentioned above, were diseased. Table No. 6, below, gives the results of these observations which were made June 20, 1908.

TABLE NO. 6

Showing Condition of the Different Varieties of Alfalfa When One Year Old. June 20, 1908.

Variety	Stand	Vigor	Prevalence of Disease	Size of Plants
9451	Fair	Fair	Present	Medium and small
11275	Good	Good	Present	Variable
12398	Fair	Fair	"	Variable
12409	Good	Good	"	Large
12671	Fair	Good	"	Variable
12702	"	Fair	"	Variable
12747	"	Good	"	Large
12748	"	Very good	"	Large
12801	"	Fair	"	Small
12816	"	Good	"	Variable
12820	"	Good	"	Variable
12846	Very poor	Very poor	"	Almost no plants
13291	Poor	Fair	"	Large
13259	Fair	Fair	"	Small
13857	Poor	Good	"	Large, varieties mixed
17698	Very good	Good	"	Low and large
18751	Good	Good	"	Variable
19508	"	Fair	"	Small
P. L. H. 3251	"	Very good	Absent	Large
P. L. H. 3252	Fair	Fair	Present	Small
12694	"	Poor	"	Frost bitten, varieties mixed
9453	"	Fair	"	Large spreading
13437	Poor	"	"	Small
12784	Fair	"	"	Variable
9322	.....	.....	.....	No plants
Gypsum 1	Very good	Very good	Present	Small

Similar observations, made June 11, 1909, when the plants were two years old, showed that all varieties were affected, including P. L. H. No. 3,251, which had promised immunity the previous season. At this time of the year, the alfalfa was from ten to twenty inches high; the majority of it had a good color, and while the blight was present in all varieties, it was not abundant enough to do any serious damage to the crop. Only a few stems of each plant were suffering and only the lower internodes of these. Such stems had the characteristic watery, yellow green color, very little blackening having occurred up to this time. Occasionally plants were found on which the attack had been so acute that they were entirely destroyed. Their location was marked only by patches of dwarfed, shriveled

stems, now dried and prostrate. Four of the twenty-six varieties were noticibly freer from the infection than the rest, namely, No. 12,398, No. 12,671, No. 12,784, and P. L. H. 3,251. It is a matter of considerable practical interest, that the first three of these are from seed which we may consider as home grown; the first is from Colorado, the second, Kansas; the third, Utah. If we are so fortunate as to find high resistance in plants from local seed, the question of obtaining resistant varieties will be much more easily solved than if we are compelled to breed up a strain from foreign seed. Table No. 7 gives the detailed observations on the variety plats, made June 11, 1909.

TABLE NO. 7

Showing Condition of the Different Varieties of Alfalfa when Two Years Old. June 11, 1909.

Variety	Vigor	Prevalence of the Disease
9451.....	Fair	Present
11275.....	Fair	Present
12398.....	Good	Present, but not serious
12409.....	Fair	Present
12671.....	Good	Present, but not serious
12702.....	Good	Present
12747.....	Good	Present
12748.....	Fair	Present
12784	Good	Present, but not serious
12801.....	Poor	Present
12816.....	Fair	Present
12820.....	Good	Present
12846.....	No plants	No plants
13291.....	Fair	" "
13259.....	Fair	" "
13857.....	Poor	" "
17698.....	Good	" "
18751.....	Fair	" "
19508	Good	" "
3251.....	Very good	Present, but not serious
3252.....	Fair	Present
9322.....	No plants	No plants
12694.	Very good	Present, but not serious
9453.....	Poor	Present
13437.....	Fair	Present, but not serious
GypsumNo.1	Good	Present, but not serious

We shall continue this part of the investigation with the same, as well as additional varieties, since the only practical way of testing out the disease resistance of these different kinds of alfalfa is to grow them under actual field conditions on infected soil, where natural agents are at work. We shall introduce, also, legumes other than alfalfa, in order to determine the susceptibility of these to the disease, so that we may be in a position to recommend other crops as substitutes where the land is so badly infected as to make profitable alfalfa growing no longer possible.

PREVENTION AND TREATMENT.

Where the areas under cultivation reach such tremendous proportions as the alfalfa fields on the mountain ranches, all schemes for soil sterilization are obviously impracticable at the outset. The same may be said of the use of germicides to be applied to the plants either in the form of sprays or otherwise, for even though some such means should be discovered by which the infection could be prevented, the cost would undoubtedly make it prohibitive. Obviously, then, as stated before, the only practical way of combating and controlling the blight is by the introduction of resistant varieties. What is being done in this direction has been mentioned before.

Our field observations during the past year seem to indicate that immunity to the disease is closely related to resistance to late spring freezing. On the one hand, those plants which were severely injured by the late spring frost were, without exception, the first to show the disease and were the worst infected later in the season; on the other hand, those varieties which grew from hardy stock and which suffered only slightly from the frost, were more nearly free from the blight. This coming year we shall endeavor to determine whether the relation between disease resistance and frost resistance is a constant one, and if it proves to be such, then we shall attempt to stamp out the trouble by securing frost resistant varieties.

In the meantime, we recommend, as a means of control, that the frosted alfalfa be clipped as soon as one is reasonably certain that there is no more danger from frost. By this means, the frost split stems, in which the disease appears to originate, will be gotten rid of, thus affording an opportunity for the early growth of a new cutting. Prof. P. K. Blinn, who has charge of the Experiment Station work at Rocky Ford, informs the writer that this practice of early clipping to remove the frost bitten shoots, which retard growth, is rapidly growing in favor among the farmers in his locality.

ACKNOWLEDGMENT.

The writer wishes to thank Prof. B. O. Longyear and Miss M. A. Palmer for the preparation of the colored plate.

EXPLANATION OF PLATE.

Fig. 1, Alfalfa stem, inoculated by smearing the freshly scraped stem with a 48 hour culture of Ps. medicaginis, x 2; 40 days after inoculation.

Fig. 2, Diseased alfalfa stem showing the yellowish, olive green color, characteristic in the early stages, x 2. Field specimen, natural inoculation.

Fig. 3, Diseased alfalfa stem showing the blackened condition in the

late stages of the blight, x 2. Field specimen, natural inoculation.

Fig. 4, Alfalfa stem, inoculated with a 48 hour agar culture of Ps. medicaginis by means of needle pricks, x 2; 15 days after inoculation.

Fig. 5, Alfalfa leaf showing diseased, yellow areas, apparently of water pore or stomatal infection, x 2. Field specimen, natural inoculation.

SUMMARY.

The disease has been known in Colorado since 1904, where, in some localities, it has caused the loss of practically eighty per cent of the first cutting.

Within the state, it is known to occur in Eagle, Garfield, Mesa, Delta and Otero counties.

The blight makes its first appearance from the first to the fifteenth of May, depending somewhat upon the locality.

The stems appear watery, semi-transparent in the early stages, and have a yellowish, olive-green color which soon changes to amber, due to the appearance and subsequent drying of a thick, clear exudate. This dried excretion gives the stems a shiny, varnished appearance, and a slightly rough feel to the touch. These stems blacken in six to eight weeks, become very brittle and are easily broken, which fact makes it almost impossible to handle the crop without an immense amount of shattering.

The disease seems to run its course with the first cutting, and is not seen again until the next year.

The cause of the blight is a germ, **Pseudomonas medicaginis, n. sp.**, which, presumably, lives in the soil and enters the plants with soil through stems which are cracked and split by late freezing.

No varieties of alfalfa entirely resistant have been obtained up to the present time.

As a means of control, we recommend that the frosted alfalfa be clipped, with the mower set low, as soon as it is reasonably certain that the danger from late frosts is past. This will rid the plants of the diseased portions, and afford an opportunity for the early growth of a new cutting. If this is done in time, the regular number of cuttings should be secured with little or no loss in tonnage.

Bulletin 160 May, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

NITRATES IN THE SOIL

An Explanation of so-called "Black Alkali" or "Brown Spots"

BY

WM. P. HEADDEN

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NITRATES IN THE SOIL

By WM. P. HEADDEN

Bulletin No. 155 of this Station, entitled "The Fixation of Nitrogen in Some Colorado Soils," gives the results of our field observations on this subject up to the latter part of the year 1909, together with those obtained in the laboratories in more detail than is absolutely necessary for a general understanding of the subject.

The people in many sections of this State understand perfectly well what is meant by the expression "brown spots." This expression was more appropriate a few years ago than at the present time, for then the term spot described quite accurately the area involved, as it does in some instances today. There are, at this time, however, areas measured by acres, which the term does not describe. What was five or six years ago a spot has now grown to involve as much, perhaps, as six, eight or more acres, and the use of the term spot is justified only on the ground that it was at first used to describe a condition as well as an area.

The condition which it describes is well known to the people of some sections of the State where it appeared a long while ago as barren places, or spots, the surface of which had a brown color. Sometimes they were shining and looked as though they were wet or perhaps oily. Some of the worst spots to which my attention has been directed appeared as though they had been wetted with a thick, black oil. The fact that nothing grew on these spots has been used by many correspondents as descriptive of them. These spots occur in a great variety of soils, from heavy adobe to light, sandy loams and silts. The spots are only local and exaggerated expressions of a condition which is becoming quite general. I have met persons who really knew but little about the matter, though they assumed to know a great deal, and who have insisted that these were seepage spots. It is true that a regular and fairly abundant supply of moisture seems to be a very favorable factor in the development of this condition, but I have not observed it anywhere, where there is an excess of moisture, especially at the surface. In some extremely bad places, I have found a very peculiar condition of the ground, beginning at depths varying from a few inches to two and a half feet below the surface which I cannot describe in any other way than as muddy. This ground is very soft and wet but retains the water so persistently that the water runs out of it very slowly, or so good as not at all. On the surface of such lands we often find a thin crust and just beneath this a mealy mass, sometimes as much as three inches thick. This brown color is by no means always associated with this wetness of the soil but is gener-

ally, though not always, associated with this mealy, or, as the people often describe it, ashy condition. We sometimes find it, the brown color, on sandy soils in which we can find no unusual amount of moisture until we get down to a depth of six or seven feet or strike gravel.

It might be inferred from what has been stated, that these brown spots, or the condition expressed by this term, occur only or mostly in low ground. While they do occur very frequently in such ground they are not at all uncommon on high ground. I have recently found excellent examples of this brown color on the College farm at Fort Collins in land which it would scarcely be possible to seep, and I know of a number of such occurrences on high mesas from 80 to 150 feet above the river bottoms, which lie immediately below them.

Persons acquainted with our soils know that we have some conditions which make drainage very difficult if not impossible. In some places, it is necessary to run a drain to almost every wet spot in a field or meadow in order to drain it. It is not an uncommon experience to find a drain within a few feet of a mud hole which has no effect on the latter. I recall opening a partially filled underdrain, laid at a depth of about four feet. I found it open and some water flowing in it, and yet water was standing on the surface of the ground ten feet away. This water was not due to recent rains or irrigation but came from the ground below. A gentleman once asked me why his alfalfa was dying, and what he should do. I answered: "Drain your land," to which he responded that it was so good as impossible, because one spot in this field might be too wet, and the alfalfa perish for the want of water within fifteen or twenty feet of it. This man told the truth, improbable as it may seem. Some may think that these brown spots are associated with bad drainage. This is not true, for while the ground is in some cases muddy, as previously stated, the soil in which this trouble is met with is more often well drained. I recall three instances in which the soil is sandy or silty and underlaid by gravel at from five to eight feet. The brown surface soil in each of these cases occurs within three hundred feet of the river which is from eight to twelve feet below the level of the land; one could scarcely find better drainage than this. In two other cases we dug holes, in one of which we struck gravel with water at five and a half feet; in the other we struck neither gravel nor water at a depth of seven feet; both soils were sandy. This condition then is not restricted to low land; is not dependent upon the variety of the soil, unless it be within very wide limits, and is not due to bad drainage though it is often observed in low, moist places.

The brown spots have often been considered as indicating the

presence of black alkali. This is not to be wondered at; in the first place the color of the surface soil is suggestive of the name and in the second place the bad effects upon vegetation which are associated with this color, lead the average man to attribute the cause of this to the only agent with which he is familiar, and which is believed to be adequate to produce this effect, namely, black alkali or sodic carbonate. Another reason which has apparently justified this inference in regard to the presence of sodic carbonate is the fact that the soil when moistened with an acid effervesces; this is due to the presence of calcic carbonate or marl, a form of limestone, and is not a proof of the presence of sodic carbonate.

The appearance of a white coating or efflorescence on the surface of the soil indicates, with us, the presence of the sulfates of lime, magnesia, and soda in the soil and usually an excess of water. The excess of water may be very injurious but these alkalis do not do any serious damage. These brown spots may or may not occur in association with the white alkalis. The intimate association of the two is so rare that we may state that they present distinct occurrences. When they occur in the same piece of land, they usually occupy distinct areas, the brown being on higher ground than the white where there is a less abundant supply of water.

Concerning the effects of the brown spots there is but one testimony, i. e., that nothing will grow. It is common to hear the expression that the white alkali is not bad but that the black is ruinous. We have had occasion to see the effects of it in many places, especially about Grand Junction, during the past season, the summer of 1909, when many apple trees and some shade trees succumbed to its influence. The effect that it produced was a burning of the leaves beginning at the tips, then extending along the edges till the whole leaf was brown. Sometimes only a few limbs on the tree were attacked in this way but very often all of the leaves were attacked and the tree was killed. I saw a great many apple trees killed during the summer of 1909 in this manner. I know of one orchard from which 110 trees have been removed this—the spring of 1910—from another 200; and in another more than 200 have been removed or are dead. There are many orchards in which a few trees, from one to twenty or more, have died. Further, there are young orchards in which the trees have refused to live. I recall several pieces of land which have been reset to orchard, peach, apple and pear several times, as many as eight according to my information, and many of the trees are dead at this time. The condition indicated by the brown color affects both young and old trees. None of the trees alluded to above, as having been pulled up, were less than 14 and some of them were 27 years old. Some of these trees were nearly two feet in diameter and had

yielded as many as fifty boxes of apples at a picking. The young orchards alluded to are not confined to one section of the State, and I recall at this time nine such orchards.

The only reason for writing of orchards rather than of other crops is that the injury is more obvious in the case of trees than of some other crops, alfalfa for instance. Complaint has been received very often that alfalfa is dying in spots. It does not follow that every spot of dead alfalfa has been killed by this so-called black alkali,but many of those that the writer has seen, have been. The same may be said of sugar beets. Sometimes large spots of bare ground occur surrounded by a very large growth of tops, with a few plants scattered throughout the area, showing a similar luxuriance in the growth of the leaves. This condition is, as a rule, associated with the brown color of the surface with a slightly incrusted, and under this a mealy condition of the surface soil. These are not the only questions which have to be considered in regard to the effects of this condition on the crops, but they are visible effects which can be easily recognized; the effects upon the quality of the crops grown cannot be seen by the eye but must be studied and determined in other ways.

Inasmuch as the injury to the trees observed during the season of 1909 did not seem to affect the roots of the trees, I hoped that there would be, at least, some recovery in the case of those trees which did not die outright at the time of the attack, but observations of such trees this spring, 1910, give but little reason to expect any recovery. Whether this is due to the fatal effects of the poison present last year, or to an injurious supply of it in the soil at the present time, I do not know. I cannot candidly state that I have seen a single case of recovery but I have, on the other hand, seen a number of cases in which there is no reason to expect the trees to live.

We have now stated something about the occurrence and distribution of these brown spots, their appearance and visible effects upon vegetation. We do not know when they began to appear but some of them have been observed for several years past. This condition is rapidly becoming more prevalent. The land occupied by the orchards referred to as having been seriously injured in 1909, had evidently not been in such bad condition before during the time that they had occupied the land, from 14 to 27 years in the different cases.

The people very generally refer to the spots as "black alkali spots," but there is no sodic carbonate or only a very little of it in such spots and the color is not due to dissolved humus as would be the case if black alkali were present. These black spots, moreover, are only very extreme cases of a condition which is very widely

distributed throughout the cultivated sections of the State. The brown streaks often seen around the edge of a wet place in some lawns, or along the margins of an irrigation furrow, are in very many instances due to the same cause. The writer has found very marked examples of this on the College farm this season, and has seen it occurring abundantly in other parts of the State.

Many people imagine that this black alkali is brought to the surface by water rising from below, such is not the fact as follows from the consideration of the general distribution of this same color in places where there is no rising water plane, others think that it is alkali dissolved out of other lands and brought into these places by seepage water, but this notion is refuted by the occurrence of just such brown spots on mesas which are themselves the highest cultivated lands in the section.

The most of us think of the soil as a mass of very small particles of rocks and some moisture which furnishes physical support and sustenance to the plants that grow in it, and nothing more. We do not think of it as teeming with life, but it is. Some of this life is beneficial to the growth of the cultural plants which furnish us our food and pleasure, but some of it is indifferent or perhaps prejudicial. Most of us have, during the past few years, heard of the part played by certain germs, which acting in succession effect the conversion of organic nitrogen, vegetable or animal, into nitric acid forming nitrates in the soil, in which form the nitrogen is taken up by the plants. This change of organic nitrogen, either of vegetable or animal origin, into nitric acid or nitrates, is called nitrification, and consists, as intimated, of several separate processes. This is not the only process going on in the soil which is dependent upon the presence of germ life, or micro-organisms. Among others is one which has to do with the building up of nitric acid or the formation of nitrates. The preceding process, nitrification, depends upon the vegetable or animal matter in the soil for its supply of nitrogen and there are three steps in the process of converting it into nitric acid, but in this one the source of the nitrogen is the atmosphere and the agent which takes the nitrogen from the atmosphere and converts it into nitric acid, respectively nitrates, is also a germ that lives in the soil. There is a number of species of this germ, one of which produces a brown pigment. This germ is abundant in our soils and apparently grows with great luxuriance. The brown color, whether in spots in a field or on the side of an irrigation furrow, or as a broad zone about the edge of a moist spot, is of itself not injurious but it is usually conclusive testimony of the presence of this germ, and a sample of soil taken from such a place will readily react for nitric acid. These germs are not necessarily detrimental to our trees and crops. If they would produce only just enough

nitric acid or nitrates, they would do us a great service, but they have built up too much of these compounds in many places. The brown color is not due to the presence of the nitrates, for they are colorless, but to a coloring matter formed by these germs. This coloring matter is soluble in water and may be partially, or at times possibly wholly, washed into the soil with the nitrates. The brown spots and soils scattered throughout our valleys and irrigated sections have been the cause of many inquiries during recent years. There are some instances in which the color may not be due to these germs but they are the cause of almost all of it. This is not the only germ which converts the atmospheric nitrogen into nitric acid or effects the fixation of nitrogen, as it is designated, but it is a common one in our soils.

It is not the brown color that does the damage, but it is the nitrates which are formed by the same agent in quantities large enough to kill the trees and other vegetation. It is the nitrates that produce the mealiness of the soil, at least nitrate or soda applied to the soil produces the same condition. Nitrate of soda applied to apple trees in excessive quantities, produces a burning of the leaves and the death of the tree in a manner similar to that shown by the trees in the orchards.

The amounts of nitrates found in the various samples of soils taken from affected areas strike one as almost incredible. We found in a sample of surface soil 6.54 per cent of sodic nitrate. This is the largest amount found in any sample and indicates the presence of nearly eleven tons in an acre of ground taken to a depth of one inch. Many samples indicate the presence of extremely large amounts of nitrates in these soils.

While these nitrates in small quantities are beneficial to vegetation they are poisonous when applied in larger quantities. The death of trees, for instance, was due to excessive quantities of nitrates formed in the soil.

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CEMENT AND CONCRETE FENCE POSTS

BY

H. M. BAINER
H. B. BONEBRIGHT

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MATERIALS USED IN CONSTRUCTING CEMENT AND CONCRETE FENCE POSTS*

By H. M. BAINER and H. B. BONEBRIGHT

PART I.

GENERAL STATEMENTS

Cement.—In cement fence post construction, it is desirable that the post be made as light and as strong as possible, and thus it is practical to use nothing but the best grade of Portland cement.

Sand.—Clean, sharp sand with grains varying in size from small to large makes the best mixture. Sharp sand is composed of sharp, angular grains of all sizes and makes a better mixture than that which is smooth and round, or "river-worn."

A sand composed of fine and coarse grains mixed, is to be preferred, because less cement will be required to fill the voids than either used by itself.

Leaves, sticks, stones or gravel should be removed by screening.

Gravel.— The same general rules used in the selection of a good grade of sand will apply to gravel. It should be composed of clean, sharp pebbles of all sizes. For post construction, the pebbles must not be too large, as they will interfere with the proper placement of reinforcement.

Broken Stone.—Broken stone used for post construction must contain no large pieces as they will interfere with the placement of the reinforcement. It is necessary to use some sand with the stone to fill voids and thus save cement. It is not desirable to use soft sandstone, soft limestone, slates, or shales. Granites, hard limestones, and coarse gravel, which has been crushed, is considered best.

Water.—The water used in making a cement or concrete mixture should be clean and free from alkali or acids.

Proportions.—On account of the difference in the total open space or voids in sands or gravel composed of different sized particles and also that more cement is required in some conditions than in others, it is often necessary to make a rough determination of the percentage of voids to the total aggregate. Where maximum strength is required about 10 per cent. more cement should be used than the total voids.

The determination may be made as follows: Secure a water-tight box or pail of known capacity, fill it with the aggregate to be used so that when it has been well shaken it will smooth off even

* This bulletin is an abbreviated edition of Bulletin No. 148 of June, 1909. A large part of the details of the tests have been omitted, but all the important results are summed up in the tables here presented.

at the top. Pour water of known amount into this until full. The volume of water used in proportion to the total volume of the receptacle determines the total voids.

The proportions used in the constructions of the fence posts in this bulletin varied from 1 part cement and 3 parts of sand to 1 part of cement and 5 parts sand. In others, gravel was used in the proportion of 1 part cement, 3 parts sand, and 3 parts gravel. It is a difficult matter to use broken stone or gravel in large quantity and place the reinforcement properly.

Measure all materials in correct proportions. This may be done with a shovel, a pail, wheelbarrow, or barrel. It will usually be advantageous to measure the water, especially where small quantities are mixed or where the same amount of mixture is made several times.

Mixing.—Where the mixing is done by hand, a flat, watertight platform, or shallow box is convenient. Measure the sand and place it in a uniform layer and over this spread the proper amount of cement. Mix this thoroughly before adding water until it shows a uniform color. The rule is to shovel it over at least three times. Now spread out the mixture, making a sort of basin in the middle into which the greater part of the water may be poured. Work in the dry edges until the water disappears, then add enough more water in small amounts to make the mixture of the desired consistency. Do not mix more material than can be used in twenty minutes.

Poured Posts.—There are two general classes of mixtures which may be used in the construction of posts; the poured and the tamped. In the poured mixture, enough water is used in mixing to make it thin enough to pour from a pail or scoop almost like water. The mixture is poured into a mold and allowed to remain in it until it has set, which is from one to five days, depending upon the time of year and the weather. In drying summer weather, from one to two days is usually sufficient. In cool or damp weather, they must be left in the molds much longer.

In order to make several posts of the poured type at once, it is necessary to have several molds ready for use. With 6 molds only 6 posts could be made at once, and it would be necessary to wait until the cement was set before 6 more could be made.

It was found that to make a good poured post, the mixture should be stirred or shaken immediately after placing in the mold. This should be done carefully to prevent displacement of reinforcement wires. This helps to remove the air from the mixture and makes a post of smooth finish.

The experiment showed that a poured post of a certain mixture was stronger than a tamped post of the same mixture. It is

enough stronger to justify anyone in constructing it in preference to the tamped one at the necessary additional expense for molds. The poured post is smoother, more nearly impervious to water, not so hard to cure, stronger, somewhat more expensive, and can be better recommended than the tamped one.

Tamped Posts.—The tamped post is one in which the mixture contains very much less water than the poured one. It contains just enough water to make it hold together well when tamped. In the manufacturing of this type of post, only one mold is necessary. The mixture is tamped into it, and the sides of the mold can be removed immediately, the post remaining on the bottom piece until the cement has set. Thus the same mold can be continuously used for making as many posts as are desired. The necessity for but one mold makes this type of post less expensive than the poured one. The results of the test made, show that the tamped post is inferior to the poured one and cannot be placed in an equal class with it.

On account of less water being used in the mixture for a tamped post than in the mixture for a poured one, the tamped post requires more water and attention in curing. It is of more open texture, less impervious to water, not as strong, and not as desirable as the post of the poured type.

Molds For Tamped Posts.—In this class of molds we find mostly the heavy cast-iron forms which are built of strong and heavy material. The most of these molds are designed to be laid upon pallettes or upon a smooth floor. The mixture is first tamped into the mold to a depth of about one inch. The reinforcement is then placed and the mold is next filled, and the mixture tamped, so that only about one inch of material remains to be filled in. The second set of reinforcement wires is put in place next and the mold is tamped full to overflowing. The last step consists in smoothing off the top of the post with a trowel and removing the mold. This is done by unfastening some form of hook or clasp, slipping the sides of the mold a little distance away from the post, and then removing the molds to the position chosen for the next post.

The principal advantage of these molds lies in the fact that they being made of heavy iron need no center stays. This gives greater speed in operation, due to the fact that there are no cross pieces to interfere with the placing of the reinforcement, the tamping of the mixture, and the smoothing off of the top of the post at the finish.

Molds For Poured Posts.—The more common forms are made of sheet iron, either galvanized or plain. For posts having a continual taper from top to bottom, sheet iron molds prove very

satisfactory, providing sufficiently heavy material is used in their construction.

The advantages of the sheet iron mold are many. They are light to handle and easy to keep clean. If properly made they are nearly water tight. This insures the user against the possible loss of cement by leakage. Another marked advantage of the sheet-iron mold is that the surface being smooth, imparts a very smooth,

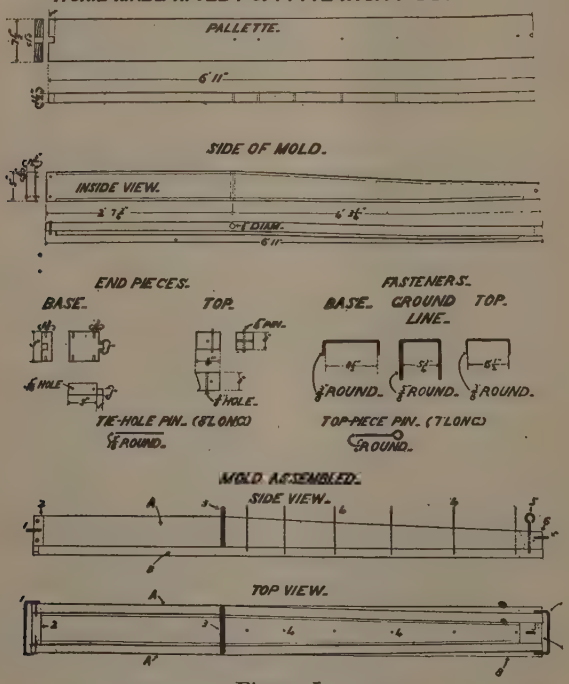

Figure I.

A Home Made Mold Giving the Proper Shape to the Post.—1. Base fastener. 2. Base end piece. 3. Ground line fastener. 4. 4, etc. Tie hole pins. 5. Top piece pin. 6. Top end piece. 7. Top fastener. A. Side of mold. B. Pallette.

glossy finish to the surface of the post. This not only adds beauty to the post, but aids in keeping out water, which might otherwise enter the cured post.

As the sheet-iron molds are made in one piece, no pallette is necessary. In hot weather the post may be removed after 48 hours, but in cold weather a much longer time is required.

In making poured posts in these molds exactly the same process is followed as with tamped posts in molds of the first class just described; with the exception that the mixture is not tamped and greater care must be exercised in preventing the reinforcement from being misplaced.

Some forms of wood molds are made and used for the purpose of making poured posts only. Any desired form may be given to the post by properly shaping the mold. This point, in favor of the wood mold, is an extremely important one, as it permits the post to be made of uniform size from the bottom to the ground line, but with a rapid taper from this point to the top. Then too, the sides of the mold may be removed after 24 hours and used again in connection with other pallettes; while the post which has not yet become sufficiently strong to be removed from the pallette lies unmolested in its original place until it is ready to move.

Molds which may be used for making either the tamped or the poured posts are much the same as the wooden molds for poured posts, except that they are stronger. The heavy, cast-iron molds could be used in making the poured posts as well as the tamped ones, but their original cost make them impracticable. The wooden molds serve the purpose equally well and are much cheaper.

Selecting the Mold.—The most important point to be considered in selecting the mold is the *shape and size* of it. Next to the shape and size we should look for ease of operation. The simple mold almost always proves to be the best, providing it has sufficient strength.

Care of Molds.—Before the molds are used they should be well coated with some kind of heavy oil. Crude petroleum is perhaps the best and cheapest material for this purpose. In case the petroleum cannot be obtained, a good oily mixture may be made by stirring about two pounds of axle grease into a gallon of gasoline. This mixture is applied to the molds with a brush. The gasoline evaporates, leaving a thin coat of axle grease spread over the entire surface of the mold. This oily mixture should be applied to the outside as well as the inside of the mold, which makes it impossible for any of the material to cling to it. With the iron molds, the oil prevents rusting. In case the molds are made of wood, the oil helps to keep out the moisture, thus preventing shrinking and swelling, and also making them easier to keep clean.

As soon as the mold is removed from the post all material sticking to it should be scraped off and the inside surface covered with a thin coating of oil. Great care should be taken not to allow the molds to become bruised or dented. If the molds are not to be used for a time, they should be thoroughly scraped and oiled, inside and out, and carefully laid away.

Reinforcement.—Cement and concrete work has the property of resisting great, crushing stresses, but when subjected to tensile stress the best of it breaks very easily. For this reason it becomes necessary to put some material possessing great tensile strength into the post, in order that the full crushing strength of the cement or concrete may be utilized. Iron is the most satisfactory material from which to make reinforcement. The reinforcement should be placed in the post as near the corner as possible. This places it as far as possible from the neutral axis thus giving it the greatest advantage in strengthening the post. In order that the reinforcements may be properly held and protected by the cement, it is a good plan to place it from ⅜ to ¾ inch in from each side.

The material used for reinforcement should be strong, light and rough enough to permit the mixture to get a firm grip upon it. It should be very rigid, with little or no tendency to spring or stretch. The experiments showed that ordinary iron or steel wire was cheapest, strongest and easiest to procure. In order to provide a means by which the cement may cling firmly to the wire, it is best to twist two small wires together instead of using one large one.

Curing the Posts.—In order for the cement to become thoroughly cured or "set" water must be supplied to aid in the action. For the first thirty days the posts should be kept wet if the best results are to be expected.

The most favorable conditions for conserving the moisture consists in curing the posts in a shed where the wind does not strike them. Under these conditions neither the sun's rays nor the wind have a chance to dry out the posts too rapidly. The posts should be thoroughly sprinkled every day for at least thirty days.

Wire Fasteners.—An inventor has devised a cast-iron socket which is placed in the post. Later the wire is fastened to the post by driving a staple into the socket or staple holder. The staples pull out easily and the sockets add greatly to the cost of the post.

Another system consists of two staples which have the prongs bent to the side. The staples are placed about one-quarter inch apart, with the prongs projecting to the side. The line wire is placed between the two staples and a nail or a piece of wire is driven down through the staples, outside of the line wire. As the tips of the staple touch the reinforcement wires, direct electric connections are established between the line wire and the ground at the bottom of the post. This, it is claimed by the patentee, insures the user against loss of stock by lightning. The system is called the "Double Staple." (See Fig. 2.)

A "single staple" may also be used, but the wire is fastened to the staple by a small "cold shut link," or wire ring. The latter system is not a very strong method of fastening, owing to the ease with which the cold shut links open. (See Fig. 2.)

Perhaps the most common method of fastening wires to cement or concrete posts consists of tying in the line wire to the post by means of a piece of smaller wire called a "tie wire" (usually No. 14 or No. 15 wire). The single tie consists of wrapping one end of the tie wire three or four times around the line wire, then passing the long end through a hole in the post and bringing it around to the face of the post where it is also wrapped around the line wire. (See Fig. 2.)

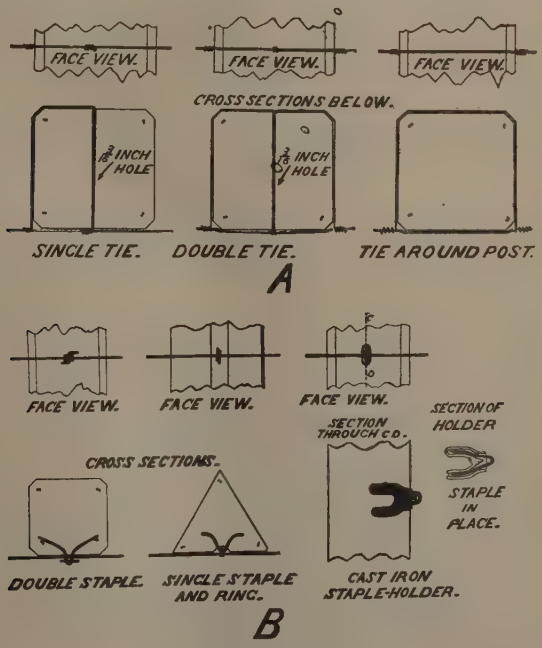

Figure II.

Different Types of Wire Fasteners.—A. Home made fasteners. B. Commercial fasteners.

The tie around post is much the same as the single tie, except that the tie wire passes around the post instead of through the hole. (See Fig. 2.) Neither the single tie or the tie around post are very strong unless the tips of the tie wire are hooked over the

body of the tie wire after the wraps have been made. This is known as the "special tie."

The strongest and perhaps the most satisfactory system of tying in the wire is the "double tie." The tie wire is bent into the form of a long staple, straddled over the line wire and both ends passed through a hole in the post. One end is brought to either side and wrapped about the line wire at the face of the post. This system insures a solid fastening and is equal in strength to any ordinary wood post fastening.

The holes in the posts are formed by No. 6 wires being placed in the post while it is soft. These wires are called "Tie Hole Pins." (See Fig. 1.) They are removed from the poured post after the cement has set for 24 hours. The pins are removed from the tamped posts immediately before the molds are removed.

The following table shows the comparative holding strength of various wire fasteners, as determined by the tests:

WIRE FASTENERS (See description of same)	KIND OF POST	No. Lbs. Required to Pull Fastener	REMARKS
Ordinary 1¾ inch staple	New Cedar	425	Average of 3 pulls. Staple was well driven into post.
Single special tie	Cement	520	Average of 2 pulls. Fence wire broke.
Double tie	Cement	510	Average of 2 pulls. Fence wire broke.
Double staple	Cement	245	Average of 3 pulls. Staples pulled.
No. 14 wire plain single tie	Cement	115	Average of 2 pulls. The wire untwisted.
No. 14 wire around post	Cement	110	Average of 3 pulls. The wire untwisted.
Cast staple holder with ordinary 1¾ inch staple driven into it	Cement	85	Ave. of 2 pulls. Staple pulled out of holder.
Cold shut-link in single staple	Cement	83	Link opened in every case. Ave. of 3 pulls.

Taper of Posts.—To obtain the maximum strength with the least amount of material, the cement post must be so shaped as to have its greatest strength at the ground line.

By making the post of uniform size from the base to the ground line, no material is wasted. The post may then be tapered from the ground line to the top. It has been found that in a 5-inch post which projects 4 feet above the ground, a taper of one inch on each side from the ground line to the top, insures almost equal strength throughout. This design gives more strength with less material than those with the continuous taper.

PART II.

THE EXPERIMENTS

These experiments were conducted for the purpose of determining the method of building the best posts at the least cost.

Apparatus.—Various commercial molds of different shapes and construction were secured. In each of these molds several posts were made in order to determine the practicability of the mold; also the best combination of mixtures and reinforcements.

The Farm Mechanics Department designed, built and used a simple home made mold which makes a post of uniform size from the base to the ground line with a rapid taper from the ground line to the top. (See Fig. 1.)

A shed which was closed on all sides with a sliding door on the east was used as the work and curing room.

Materials—The sand and gravel used was clean and sharp, with all sizes of grains varying from small to large. There was a very small percentage of mica in the sand, which was objectionable. One brand of Portland cement was used for making all posts.

A total of 238 line posts and 8 corner posts were built and tested during the experiment, the records of which are found in the following tables:

Cost of Materials.—In figuring cost of materials the following prices were used:

Sand and gravel, $1.00 per cubic yard.
Cement, 60 cents per sack.
New reinforcement, 4 cents per pound.
Old barbed wire, 2 cents per pound.

The Test.—In making the test, the posts were placed under as near fence conditions as possible. All line posts were set and firmly tamped into the ground so that 4 feet and one inch projected above the surface. By means of a wire, a dynamometer was attached to the post exactly 4 feet from the surface of the ground. A steadily increasing force was applied to the dynamometer by means of a block and tackle, until the first visible crack appeared in the post when a reading was made. The force was then increased until the post gave away completely when the final reading was made.

In making the posts enough of the mixture was provided for the construction of three posts at once. The three were cured alike for 60 days and were tested at the same time. The tables show the average results of the test on the three posts as one.

In the reinforcement the short wires mentioned are two feet long and are placed in the post so the top extends about 12 inches

above the ground line and the bottom about 12 inches below. One of these extra wires is placed in the face side of the post and the other in the back, so that they help to bear the strains on the post. In case of four extra wires, one is placed in each corner of the post with the other reinforcement wires.

TABLE NO. 1.—Poured and Tamped Posts.*

Size, 5x5 inches from base to ground line, tapering to 3x3 inches at top. Length, 6 feet 6 inches. Cured weight, 115 to 120 pounds. Mixture, 1 part cement and 3 parts sand by measure. Cost for cement for posts, 16.2 cents; sand, 3.7 cents. For cost of reinforcement, see table.

REINFORCEMENT			COST	FINAL BREAK			
				Poured Posts		Tamped Posts	
Kind of Wire	Weight per post	Cost per post	Cost of Material in each Post	Pounds to break	Remarks	Pounds to break	Remarks
No. 10, 4 twisted strands of 2 wires	2½	10.0c	29.9c	307	Wires broke	240	Mixture broke, wires did not break
No. 10, 8 strands crimped	2½	10.0c	29.9c	254	Wires slipped and finally broke	263	Wires slipped, did not break
No. 6, 4 long wires hooked at ends	2¾	10.6c	30.5c	232	All wires slipped	184	All wires slipped
New barbed, 4 long strands	1¾	6.6c	26.5c	188	Wires broke (Post was 130 days old)	123	Wires broke
Old barbed, 4 long strands	1¾	3.3c	23.2c	158	Wires broke	128	Wires broke
New barbed, 4 long and 2 short	2	8.0c	27.9c			198	Wires broke
Old barbed, 4 long and 2 short	2	4.0c	23.9c	200	Mixture broke above extra wires		
Old barbed, 4 long and 4 short	2¾	5.5c	25.4c	229	Long wires broke above extra wires		
No. 10, twisted 4 long and 2 short	3	12.0c	31.9c	290	Extra wires did no good	160	Extra wires did no good

* This table is a summary of Tables 1 and 2, Bulletin 148, Colo. Exp. Sta.

Amount of Labor Required for Making Posts.—No definite statements can be made as to the amount of time required to make a cement or concrete fence post. The amount of time will vary with conditions, handiness of materials, methods of mixing, etc. According to data obtained in the experiment, two men mixing by hand, with everything reasonably handy, can make from three to five 5-inch poured line posts per hour. Figuring labor at $2.00 per day, ten hours for each man, the cost for making a post would amount to about 10 cents each. Three men with a small home made mixer and a two horse-power gasoline engine for driving it,

would be able to make at least twice as many posts as two men working by hand and the cost for making would be very much less.

The Effect of Alkali on Cement and Concrete Posts.—It has been found that some soils contain an excessive amount of alkali, which has a tendency to destroy concrete work. While no experimental work has been done to test the effect of such soils upon cement or concrete posts, it has been conclusively proven that cement drain and sewer tiles which come in contact with water which has percolated through these alkali soils are soon destroyed.

While it might be possible that the action on cement or concrete posts would be slower than in case of the tiles, it is probable that the post would eventually be destroyed.

For further information in regard to the effect of alkali on cement construction see Bulletin No. 69, of the Montana Agricultural Experiment Station, and Bulletin No. 132, Agricultural Experiment Station of the Colorado Agricultural College.

TABLE NO. 2.—Poured and Tamped Posts.*

Size, 5x5 inches from base to ground line, tapering to 3x3 inches at top. Length, 6 feet 6 inches. Cured weight, 115 to 120 pounds. Mixture, 1 part cement and 3 parts sand, by measure. Cost for cement per post, 16.2 cents; sand, 3.7 cents. For cost of reinforcement, see table.

REINFORCEMENT			COST	FINAL BREAK			
				Poured Posts		Tamped Posts	
Kind of Wire	Weight per Post	Cost per post	Cost of material in each post	Pounds to break	Remarks	Pounds to break	Remarks
No. 10, 4 twisted strands of 2 wires	2½	10.0c	26.9c	222	Mixture broke, wires not well placed	192	Wires broke
No. 6, 4 long wires hooked at ends	2⅝	10.6c	27.5c	222	Wires slipped	162	Wires slipped
No. 10, twisted 4 long and 2 short	3	12.0c	28.9c	322	Mixtures and wires about equal		
Old barbed 4 long strands	1⅔	3.3c	20.2c	95	Wires broke, poorly placed	137	Wires broke
Old barbed, 4 long and 2 short	2	4.0c	20.9c	127	Poor wire. Wires broke	142	Wires broke
New barbed, 4 long and 2 short	2	8.0c	24.9c	172	Wires well placed, cement broke	170	Wires not well placed
Old barbed, 4 long and 4 short	2¾	5.5c	22.4c			196	Wires broke
New barbed, 4 long strands	1⅔	6.6c	23.5c			160	Wires broke

* This table is a summary of Tables 3 and 4, Bulletin 148, Colo. Exp. Sta.

TABLE NO. 8.—Poured and Tamped Posts.*

Size, 5x5 inches from base to ground line, tapering to 3x3 inches at top. Length, 6 feet 6 inches. Cured weight, 110 to 112 pounds. Mixture, 1 part cement and 5 parts sand, by measure. Cost for cement per post, 17 pounds, 10.2 cents; sand, 1 cubic foot, 3.7 cents. For cost of reinforcement, see table below.

REINFORCEMENT			COST	FINAL BREAK			
				POURED POSTS		TAMPED POSTS	
Kinds of Wire	Weight per Post	Cost per Post	Cost of material in each post	Pounds to break	Remarks	Pounds to break	Remarks
No. 10,4 twisted strands of 2 wires	2½	10.0c	23.9c	235	Mixture broke (poor)	97	Mixture not strong enough
No. 10, twisted 4 long and 2 short	3	12.0c	25.9c	220	Extra wires did no good	98	Posts split. Mixture weak
Old barbed, 4 long strands	1⅔	3.3c	17.2c	113	Wires broke	117	Wires broke
Old barbed, 4 long and 2 short	2	4.0c	17.9c	137	Mixture and wires about equal	113	Mixture and wires about equal
New barbed, 4 long strands	1⅔	6.6c	20.5c	123	Mixture and wires about equal	108	Mixture and wires about equal
New barbed, 4 long and 2 short	2	8.0c	21.9c	140	Wires broke	103	Wires poorly placed
No. 14, 4 twisted strands of 3 wires each	1⅔	6.6c	20.5c	130	Wires broke		
No. 14, 4 long and 2 short, 3 twisted strands each	2	8.0c	21.9c	175	Wires and mixture about equal		

* This table is a summary of Tables 5 and 7, Bulletin 148, Colo. Exp Sta.

TABLE NO. 4.—Poured Posts.*

Size, 4x4 inches at base, tapering to 3x3 inches at top. Length, 5 feet 6 inches. Cured weight, 80 pounds.

REINFORCEMENT			COST OF MATERIAL AND FINAL BREAK			
			Mixture, 1 part cement and 3 parts sand.		Mixture, 1 part cement and 4 parts sand.	
Kind of Wire	Weight per post in lbs.	Cost per Post	Cost of Material in Post	Pounds to break post	Cost of Material in Post	Pounds to break post
No. 10, 4 twisted strands of 2 wires	2½	10.0c	23.3c	183	20.6c	168
Old barbed, 4 long strands	1⅝	3.3c	16.6c	108	13.9c	65
New barbed, 4 long strands	1⅝	6.6c	19.9c	105	17.2c	88
No. 14, 4 strands of 3 twisted	1⅝	6.6c	19.9c	102	17.2c	62
No. 14, 4 long and 2 short strands of 3 twisted	2	8.0c	21.3c	185		

* This table is a summary of Tables 6 and 8, Bulletin 148, Colo. Exp. Sta.

The Three Cornered Post.—The following conclusions are drawn after testing 23 triangular posts. Size, 7 inches on each side at the bottom, tapering to 5 inches on each side at the top. Mixture, 1 part cement and 3 parts sand, by measure. Cost of material varying from 14 cents to 19 cents each.

The three cornered post which is advocated to some extent, does not have as many points in its favor as it may seem. In the first place an equal amount of reinforcement in each corner of the post cannot make a post of equal strength from two opposite directions. If a force is brought to bear against one of the flat sides of the post towards the opposite corner, the material in the corner will crush long before the wires will break on the side from which the force is exerted. On the other hand, if a force is brought to bear against one corner of the post towards the opposite flat side, the single reinforcement in the corner will break before the mixture has begun to crush on the flat side.

An extra reinforcement in the corner on which the force is exerted towards the opposite flat side will make it practically as strong as the flat side. But when the force is again applied to the flat side towards the single corner which is doubly reinforced, the mixture in the corner gives away too soon and it is no better than with but a single reinforcement.

TABLE NO. 5.—Poured Posts.

Size, 5x5 inches from base to ground line, tapering to 3x4 inches at top. Length, 6 feet 6 inches. Cured weight, 115 to 120 pounds. Mixture, 1 part cement, 3 parts sand, and 3 parts gravel, by measure. Cost of cement per post, 14 pounds, 8.4 cents; sand and gravel, 1 cubic foot, 3.7 cents. For cost of reinforcement, see table below.

REINFORCEMENT			TEST		COST	REMARKS
Kind of Wire	Weight Per Post Lbs.	Cost Per Post	Final Break in Lbs.	Location of Break Above or Below Ground Line	Cost of Materials in Post	New Wire is Figured at 4c per Lb. and Old Wire at 2c per Lb.
4 strands of 2 wires twisted No. 10	2⅓	10.0c	218	Ground line Ground line 4 in. below	22.1c	Wires broke on 2 and mixture broke on one
4 long and 2 short twisted strands No.10	3	12.0c	330	4 in. above 12 in. above 4 in. below	24.1c	Wires broke
4 long strands old barbed wire	1⅔	3.3c	110	Ground line Ground line Ground line	15.4c	Wires broke
4 long and 2 short old barbed wire	2	4.0c	118	20 in. above 24 in. above 15 in. above	16.1c	Wires broke, not well placed
4 long strands new barbed wire	1⅔	6.6c	143	4 in. below Ground line Ground line	18.7c	Wires broke
4 long and 2 short new barbed wire	2	8.0c	123	Ground line 3 in. above 10 in. above	20.1c	Wires broke
4 long strands of 3 twisted wires, No. 14	1⅔	6.6c	123	Ground line 27 in. above Ground line	18.7c	Wires broke
4 long, 2 short strands of 3 twisted No. 14	2	8.0c	143	Ground line 7 in. below 4 in. below	20.1c	Mixture broke on two and wires broke on one

TABLE NO. 6.—Corner Posts.

Size, 8x8 inches from base to ground line, tapering to 5x5 inches at top. Length, 8 feet. Cured weight, 360 pounds. Mixture, 1 part cement, 2 parts sand, and 3 parts of gravel, by measure. Cured 90 days. Cost for cement per post, 51 pounds, 30.6 cents; sand and gravel, 3 cubic feet, 11.1 cents. For cost of reinforcement, see table below. Test shows pull exerted in pounds as by each of two fences pulling at right angles.

REINFORCEMENT			TYPE	TEST			COST	REMARKS
Kind of Reinforcement	Weight Per Post Lbs.	Cost Per Post	Poured or tamped	First Crack in Lbs.	Final Break in Lbs.	Location of Break	Cost of Material per Post	All reinforcements figured at 4c pound excepting old barbed wire at 2c.
2-8 ft. and 2-5 ft. pieces ½ in. rod on tension side	16	64c	poured	7200	8500	at brace	$1.057	Short wires extended from below ground line to above brace line
Same as above	16	64c	tamped	5050	5600	at brace	1.057	Short wires extended from below ground line to above brace line
14 strands old barbed wire on tension side.	8	16c	tamped	6300	7300	at brace	.577	Mixture broke
Same as above	8	16c	poured	5900	7400	at brace	.577	Mixture broke
10 twisted strands No. 10. on tension side	8	32c	tamped	5400	7300	4 in. below brace	.737	Mixture broke
Same as above	8	32c	poured	6300	6650	4 in. above brace	.737	Mixture broke

Size, 7x7 inches at base, tapering to 5x5 inches at top. Length, 8 feet. Cured weight, 250 pounds. Mixture, 1 part cement, 2 parts sand, and 3 parts gravel, by measure. Cured 90 days. Cost of cement per post, 36 pounds, 21.6 cents; sand and gravel, 2 cubic feet, 7.4 cents. For cost of reinforcement, see table below.

REINFORCEMENT			TYPE	TEST			COST	REMARKS
Kind of Reinforcement	Weight Per Post Lbs.	Cost Per Post	Poured or tamped	First Crack in Lbs.	Final Break in Lbs.	Location of Break	Cost of Material Per Post	All reinforcements figured at 4c pound excepting old barbed wire at 2c.
8 strands old barbed wire 2 in each corner	4½	9c 2c lb.	poured	2700	3600	at braces	$0.38	Mixture broke
8 strands new barbed wire 2 in each corner	4½	18c 4c lb.	poured	3225	4050	at braces	.47	Mixture broke

HOLLOW POSTS.

It has been suggested that the cement and concrete posts should be made hollow. The hollow post would require less mixture and it would also be lighter. As the material in the center of the post does not have a good opportunity to act to the best advantage in compression, it is argued that the strength of the hollow post would be nearly as great as that of the solid post.

In case time is of little value it would probably prove mor economical to build hollow posts. As the amount of reinforcemen is not affected by the change from the solid to the hollow post, onl the saving in cement, sand and gravel need be considered. It is a easy matter to compute the saving accomplished by the making o hollow posts, and then by knowing the cost of labor, the economy of building them may soon be calculated. With cement at 55 cent per sack and sand at $1.00 per yard, one cubic foot of 1 to 4 mixtur costs 18 cents. If a 1½ inch hole were to be left in the center of post 7 feet long about 1½ cents' worth of material would be saved With labor at 15 cents per hour, 6 minutes might be given to th extra work of making the post with the hollow core.

In case of alkali soils the hollow center gives additional ex posed surface upon which the alkali may act. In a 4-inch squar post with a 1½ inch core, the extra surface amounts to about 2 per cent. of the original lateral surface.

Finally there is a serious question as to the relative strengt and durability of the hollow post as compared with the solid one.

CORNER POSTS AND GATE POSTS.

In the building of a fence with cement or concrete posts, th corner and gate posts must be especially strong, so as to prevent th pull of the wires coming upon the line posts. All the pull of th wires should be borne by the corner or gate posts. With this i mind the designer should aim not only to build a very strong post but the system of bracing should receive special attention.

As the cement posts are not as strong as wood posts, we can not use the same bracing systems, which are so commonly in us in wood post fence construction. It has been found advisable t place the brace so that it supports the post at a point very little, i any, above the middle of the post. For the reason that the post are strong in compression, but do not stand as much pull as wood posts, it proves advisable to place the brace against the brace pos at least one foot below the ground line; thus the post distribute the pressure at the end of the brace against an area of ground equa to the surface covered on the opposite side of the post.

There should be several wires connecting the brace post and the corner or gate post together. These wires should be placed under the ground at a depth of about one foot. By having these wires tight the corner post cannot move unless the brace post moves and as this is securely fastened to it, the whole becomes a unit offering a rigid resistance to the pull of the fence.

In case of a corner post, the wires may be fastened by wrapping them around it, but the most satisfactory way is to cast wire staples in the post. These staples should extend into the post far

enough to be wrapped around one or more of the reinforcement wires.

The hinges for gates may also be cast in the posts when it is desired to do so.

Corner and gate posts are usually reinforced in the same way as line posts. It is unnecessary, however, to place reinforcement wires on the inner sides of the corner posts, as the outer sides bear almost all of the tension.

With the tapered posts, it is desirable to construct the face sides straight; this brings all of the taper on the other two sides. Small lugs or shoulders should be cast on each brace side of the post, against which the brace is placed.

The ordinary five-inch line post proves to be strong enough to act as a brace post for an eight-inch corner post.

The following table gives a summary of breaking strength and cost of materials of some of the best poured posts, which were made and tested in this experiment.

MIX-TURE	DESCRIP-TION	REINFORCEMENT								
		4 Long No. 10 Twisted	4 long 2 short No. 10 twist-ed	4 long New Barbed Wire	4 long Old Barbed Wire	4 long 2 short new barbed	4 long 2 short old barbed	3 long No. 19 in. band iron	4 long 4 short old barbed	6 long old barbed
1 to 3	Ground line 5x5 top 3x3	307 lbs. 29.9c	290 lbs. 31.9c	188 lbs. 26.5c	158 lbs. 23.2c	none none	200 lbs. 23.9c			
1 to 4	Ground line 5x5 top 3x3	222 lbs. 26.9c	322 lbs. 28.9c	none none	95 lbs. 20.2c	172 lbs. 24.9c	127 lbs. 20.9c			
1 to 5	Ground line 5x5 top 3x3	235 lbs. 23.9c	220 lbs. 25.9c	123 lbs. 20.5c	113 lbs. 17.2c	140 lbs. 21.9c	137 lbs. 17.9c			
1 to 3	Base 4x4 top 3x3	183 lbs. 23.3c	none none	105 lbs. 19.9c	108 lbs. 16.6c					
1 to 4	Base 4x4 top 3x3	168 lbs. 20.6c	none none	88 lbs. 17.2c	65 lbs. 13.9c					
1 to 3 3	Ground line 5x5 top 3x3	218 lbs. 22.1c	230 lbs. 24.1c	143 lbs. 18.7c	110 lbs. 15.4c	123 lbs. 20.1c	118 lbs. 16.1c			
1 to 3	Base 5x5 top 3x3 horse shoe shape	202 lbs. 23.3c			133 lbs. 16.6c			157 lbs. 22 3c	148 lbs. 18.8c	
1 to 3	Triangular Base 7x7 top 5x5			110 lbs. 18.0c						147 lbs. 15.9c

Strength of cement posts compared to new wood posts tested under like conditions.

KIND OF POST	SIZE OF POST	BREAKING STRENGTH	REMARKS
(1) Best cement post tested	5x5 in. at ground line tapering to 3x3 in. at top	322 lbs.	
(2) Cement	Same as above	307 lbs.	
(3) Cement	4x4 in. at base tapering to 3x3 in. at top	185 lbs.	The post was 3.6x 3.6 in. at ground
(4) Split cedar (new)	3.6x3.6 in. at ground line	613 lbs.	Same size at ground as No. 3 above
White pine (new)	4x4 in. at ground line	2000 lbs.	
Red spruce (new)	4½x4½ in. at ground line	2400 lbs.	
Red spruce (new)	5x5 in. at ground line	3350 lbs.	

CONCLUSIONS.

Poured posts are easier to make than tamped ones. They are somewhat more expensive because one mold will make but one poured post per day, while the same mold may be used for making as many tamped posts as the builder can mix and tamp in the same time.

According to the tests made poured posts are a little over 25 per cent stronger than tamped ones of the same size, mixture and reinforcement.

Poured posts are not so porous as the tamped ones and are therefore more nearly water proof, thus making them better able to withstand the action of frost and alkali.

The poured post is enough better in every respect to justify its construction and use in preference to the tamped one.

Most commercial molds make a post which tapers from the base to the top, but the most economical mold is one which casts a post as large at the ground line as at the base, tapering from the ground line to the top. For a description of this form of mold, see Fig. 4.

The best form of post is one which is equally strong from all directions. The square, or round post, fulfills this requirement. The triangular post does not meet the requirements because it cannot be economically constructed so as to be equally strong from all directions.

To be economical, the amount of reinforcement should be in proportion to the size of the post and strength of the mixture. See tables.

The material used for reinforcement should be strong, light and rough enough to permit the mixture to get a firm grip upon it. It should be very rigid, with little or no tendency to spring or stretch.

The smooth reinforcement tends to slip even if hooked at the ends.

Two or more wires twisted together make as satisfactory a reinforcement as can be obtained.

Crimped wire tends to straighten and thereby breaks pieces out of the post at the point of greatest stress.

The reinforcement should be placed in each corner of the post at a depth of from ⅜ to ¾ of an inch from the surface.

There are several commercial wire fasteners now found on the market, the most of which are either cumbersome or expensive. For a simple and satisfactory fastener, see cut of fasteners. (Fig. 5, A.)

The posts should be cured in the shade for at least 60 days, the first 30 days of which they should be sprinkled daily.

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The Agricutural Experiment Station

OF THE

Colorado Agricultural College

RABIES

BY

GEO. H. GLOVER

AND

B. F. KAUPP

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Fig. 1.

FIG. 1.—A case of dumb rabies. Note the peculiar attitude and the dropped jaw. Reproduced from K. C. V. C. Bul.—Kinsley & Kaupp.

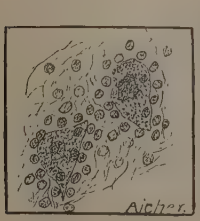

Fig. 2.

Fig. 3.

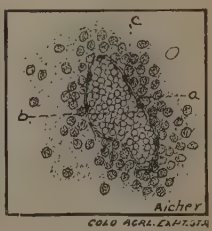

Fig. 4.

FIG. 2.—Section from plexiform ganglion showing degenerative changes with round cell infiltration. Babes' corpuscles.

FIG. 3.—Nerve cells from Hippocampus showing granular condition of cytoplasm.

a.—Nuclei.

b.—Negri bodies.

FIG. 4.—Section from Medulla.

a.—Blood vessel wall.

b.—Red blood cells.

c.—Perivascular Infiltration.

RABIES

By DR. GEO. H. GLOVER, Head of Veterinary Dept. and DR. B. F. KAUPP, Pathologist, Veterinary Dept.

DEFINITION: Rabies is an acute infectious disease, usually transmitted by the bite of a rabid animal. It effects the cerebro-spinal system, and is accompanied by extreme nervous excitability.

History of Rabies in Other Countries.

Rabies was recognized as a distinct disease by the Israelites and Egyptians as far back as 322 B. C. We find descriptions of it by Horace, Celsus, Virgil, and other writers of those times.

Rabies is most common in the north temperate zone, although it may be found in nearly every part of the world, and from the sea levels to the high altitudes. It is usually found most prevalent in the most densly populated districts, where the conditions are most favorable for its spread.

New Zealand, Tasmania and Australia are reported not to be infected with rabies. All animals, and especially dogs, are kept under strict quarantine for a period which is calculated to exclude the possibility of its introduction into these countries. St. Helena and the Azores are said never to have suffered from the disease. In many German cities, including Berlin, muzzling ordinances have done most to stamp out the disease. Through strict enforcement of the muzzling ordinances in England no case of rabies has been reported since 1901, and in Ireland since 1903. It is interesting to note that at one time rabies was so common in London that many people were afraid to venture on the streets at night. In France 1892 cases of rabies were reported during the year 1907, and in Belgium 226 cases with 179 suspected ones were reported the same year. During this same year 254 cases were reported in Austria, 55 in India (British), 1825 in Hungary, 701 in Italy and 36 in the Netherlands.

The Prevalence of Rabies in the United States.

This disease was quite rare in this country till about 30 years ago. Since that time new centers of infection have been constantly appearing.

The presence of rabies has been positively proven in twenty-two states and probably exists in all.

In the District of Columbia, during 1907, rabies was identified in 37 dogs, 4 dingoes, 1 cow, 1 sheep and 1 cat. During 1905, from one pathological laboratory in Kansas City, 31 cases were reported as follows, 1 cat, 1 hog, 1 sheep, and the balance dogs. From this it will be seen that most cases occur in dogs.

History of Rabies in Colorado.

The recent outbreak of rabies in Colorado is said to have started in Greeley about two years ago, when a dog which had just been brought to that place from the east, developed the disease. The in-

fected area at this time seems to be confined to the eastern portion of Colorado and extends from about 50 to 75 miles north of Denver to as far south as Pueblo. The most thickly populated districts of this territory, as Denver and its vicinity, have the most cases.

The beginning of this investigation was on August 31, 1908, when a call came from Greeley, where several cases had been diagnosed as rabies among dogs, cattle, etc., In this investigation the disease was studied in one horse, two cattle, and eight dogs. This covered a period of less than six months. Laboratory findings were confirmed by repeated animal inoculations. Several people bitten by rabid dogs were advised to proceed to a Pasteur Institute and take anti-rabic treatment. The mayor and city council upon receipt of an official report that rabies existed in that city, enforced a muzzling ordinance. All dogs on the highways not muzzled were destroyed. The result of this proceedure was that rabies was stamped out of Greeley.

Later a typical case was received from Loveland. In a few weeks two cases came from Longmont, and about ten months later a third case. This last, a dog, had bitten another and in thirty-five days the dog bitten developed rabies. One case has been received from Fort Lupton, one from Platteville, and three from Castle Rock. Two serious outbreaks of rabies, due to stray rabid dogs, have occurred within the past few months near Denver.

Since September, 1909, forty-three animals or their heads have been received at this laboratory from Denver. All but one head were from suspected cases of rabies. Of these heads two were from cattle, one cat, one wolf and the balance from dogs. Of these heads the brain of one was in a state of puterfaction and could not be examined and six did not show lesions of rabies. The balance, including two heads of cattle, showed lesions of rabies.

Animals Affected.

All animals may develop rabies when bitten by one that is rabid. This includes horses, cattle, sheep, hogs, dogs, cats, pole cats, mice, wolves, man, etc.

Transmissibility.

So far as has been proven the disease is only transmitted by the bite of a rabid animal or by inoculation.

Virulency of the Saliva.

The virus may be introduced into an already existing wound through holding an autopsy, or by the animal licking a wound. It is usually done by the bite of a rabid animal. By careful experiment it has been found that the saliva of a dog may contain the virus for seven or eight days before developing symptoms of the disease. As the virus is contained in the saliva, the teeth inflicting the wound carry the infection and deposit it in the wound.

It is a mistake to hasten to kill a suspected dog. The symptoms, if any, should be noted, and later, if rabies is diagnosed, the dog may be killed, and if desired, the head sent to the laboratory for microscopic examination.

Persons or Animals Bitten.

The wound should be cauterized at once, before the virus has had time to find its way beyond the point of reach of the cautery. This can best be done by the use of a red hot iron or by the use of dilute nitric or sulphuric acid applied deep into the wound with a stick, if nothing better is at hand. Nothing short of reaching the entire depth of the wound will be effective and this must be done at once. Lyssophobia, or fear of rabies, is common in nervous persons, who have been bitten by a dog rabid or normal. Should the dog biting a person be found free from rabies after keeping him confined for ten days, or a microscopic examination or by rabbit inoculation, the mind of the person should be set at ease. Should the dog be found to be rabid, the Pasteur Treatment, being a sure preventative when the person goes early, should also set the mind at rest.

Period of Incubation.

The period from the time the bite is inflicted until the symptoms of the disease appear, varies from three or four weeks to several months. It is doubtful if any authentic cases have developed after eighteen to twenty-four months.

The length of time that elapses from the bite until the animal developes the disease depends largely on two factors: first, the location of the wound, and second, the severity of the lacerations. The fact has long been established that the virus travels the course of the nerves. Thus if the wounds are in the facial regions the course from the inoculated point to the brain is short and the disease develops quicker. The deeper and more severe the lacerations, the greater the quantity of saliva introduced into the wound and the more dangerous it is. Thus in scratches the danger is not so great as when the tooth penetrates the flesh. Bleeding has a tendency to wash out some of the virus and lessen the danger.

In dogs, street rabies usually develops in from 23 to 35 days, in horses and cattle in from 4 to 6 weeks, in hogs and cats the time is about the same as in dogs. Street rabies is that form found from natural infection. The virus from one animal may be more or less virulent than from another.

The disease develops in pups quicker than in adult dogs, and in children in less time than in adults. In mature people the period of incubation is from 40 days to three months. While the mortality is considered to be 100 per cent., yet, conservative estimates place the number of those bitten that develop the disease at 16 to 20 per cent. Under certain conditions the percentage runs higher. The clothing or the thick coat of hair, in animals, has a tendency to clean the teeth of saliva and lessens the probability of infection.

Dumb Rabies.

The form known as dumb rabies may characterize the disease from the first or may develop in the later stages of the furious type. This form of disease runs a more rapid course, and by some is

considered to be due to a greater degree of infection. There is a greater toxemia. Dogs with this type usually die in from 3 to 4 days after the symptoms have fully developed.

Symptoms.

The first symptoms noted will be a change in the disposition. The kind playful dog will become morose, fretful, and easily excited. In these earlier stages, if running at large, he may pick up and swallow sticks, hair, and even stones. There is a tendency to lick and gnaw the point at which he was bitten. This part may itch and possibly cause pain. He is prone to crawl under the porch or other place and hide a part of the time, coming out to eat and again seeking seclusion. At this stage he may leave home and bite men and animals that chance to come his way. He may return home after several hours in an exhausted state or he may never return. The jaw drops from paralysis and the owner thinks the dog has a bone in his throat. He eats and drinks with difficulty or not at all, owing to the partial or complete paralysis of the throat. He may bark but his bark is drawn out into a long howl. This howl, if once heard, will never be forgotten. The dog may still know his master but has a tendency to try and bite or attack any one he does not know. Later he does not even recognize his master. If in a cage he will bite or snap at any stick poked at him. If tied he will try to chew the rope and free himself. The ears may be erect and trembly. The dog is ever alert to any noise, and is always disturbed by it. He stares, his eyes at first moist later become dry. This is due to the cessation of the tear secretion. Finally he becomes paralized, first in the hind quarters, then in the fore, and death ends his suffering. Oftentimes the tongue is protruded and more or less paralized and as a result of exposure to the atmosphere is oftimes dry and black. Figure 1, shows a photograph of a dog with dumb rabies.

Furious Rabies.

In furious rabies the animal is more irritable than in the dumb form. There is a greater tendency to bite. The jaw is not dropped or paralized until the very last stages. In the furious type the dog may live from six to eight days after the symptoms are well developed. Horses and cattle more often develop the furious type. The writer has seen a case in the horse, in which an ordinary box stall was not strong enough to hold the animal, so furious was he in his spasms. The horse makes violent efforts to bite or attack, the cow more often tries to butt any animal or person that comes near.

Post Mortem Findings.

The dog, or any animal, to be sent to the laboratory should not be shot through the brain, as that lacerates the brain and causes hemorrhages into its substances. This greatly interferes with a detailed examination. The proper, and one of the most humane ways, is to shoot the dog or other animal through the heart. The head should be cut off in such manner that three or four inches of the neck remains with the head. This enables the securing of the nerve centers for mi-

croscopic study. A sectioned surface of the brain is usually dark in appearance. Occasionally a bloody spot, small in size, can be seen under the coverings of the cord. This is especially noticeable from the cords of the experimental rabbit inoculations, otherwise the cord and brain has a normal appearance. The changes are so slight in their appearance that nothing definite can be told short of a microscopic examination. In the stomach may be found sticks, straws, shavings, etc, picked up while running at large. Aside from these substances, the stomach is empty. There should be observed an absence of all acute diseased lesions, at the autopsy.

Microscopical Examination.

For microscopical examination, the brain must be in good condition. Brains that are in a state of putrefaction cannot be satisfactorily examined. The first definite microscopic lesions of rabies to be pointed out, was by V. Babes in 1892. He found degeneration of the nerve cells in the medulla and the plexiform ganglion. The degeneration in the medulla was particularly noticeable near the central part of the ganglionic portion. There was observed an invasion of small round cells in the spaces occupied by the cytoplasm of the cells. These he called rabic tubercles which are now sometimes called Babes tubercles or corpuscles. Figure 2 shows one of these tubercles from the plexiform ganglion.

In 1893, A. Negri called attention to certain bodies always found in the nerve cells of a dog or other animal dead of rabies. To these was given the name Negri bodies. Since that time these bodies have been studied in more detail by many scientists and are now believed by the foremost workers to be protozoan in nature. Different stages of their development have been studied which corresponds to the different stages of the disease. These bodies stain characteristically. They contain eosinophilic granules. Figure 3 shows nerve cells containing Negri bodies.

Delafield & Prudden call special attention to the peri-vascular infiltration which usually accompaines this condition. Figure 4 gives an illustration of this phase.

Animal Experiment.

When a person is bitten by a dog suspected of being rabid and the laboratory findings are not satisfactory the laboratory worker can, if the brain is still fresh and is not contaminated, inoculate an animal. In doing this an emulsion is made from a small part of a certain part of the brain. The rabbits skull is trephined and a small part of the emulsion is injected under the coverings of the brain. If care in technique is taken the animal will appear healthy, and eat and drink until the symptoms develop, which is usually about the 14th to the 16th day. If the technique has been at fault and infection taken place the rabbit will die of septic infection long before the time for rabies to develop. Freezing does not destroy the virus and it will resist putrefaction for a long time. Drying will soon destroy it.

Control and Eradication of Rabies.

This most terrible disease is the most easily eradicated of all contagious diseases as shown by the results in England, where rabies once prevalent, is now practically unknown. As the spread of the disease is by the bite of a dog in practically every instance, the muzzling of all dogs with the destruction of those not kept muzzled, is the easy solution of the problem. This muzzling must be universal throughout the infected district.

Pasteur Treatment.

Soon after Pasteur had perfected the vaccine for Anthrax, which was about 1880, his attention was called to a little girl in a ward of a hospital dying of rabies. As a result of the study that followed, Pasteur by experimenting on the lower animals perfected the vaccination method which is still used to vaccinate and protect the lives of people when bitten by a rabid dog. As early as 1880 it was a recognized fact that drying practically destroyed the virus of rabies. Pasteur took advantage of this fact by drying the cord of rabbits dead of rabies, over potassium hydrate thus attenuating it, and making a vaccine. By injecting a certain portion of the cord, so treated for 14 days, under the skin, in the form of an emulsion, followed once a day with a like injection, gradually using cord less attenuated, in 21 days the person is immune from the disease and the treatment is complete.

Danger of Milk and Meat.

In regard to the infectiousness of milk from rabid animals it must be considered at all times dangerous, as some experiments have proven that the milk is infectious. Some experiments conducted along this line have given entirely negative results. The young should be taken away from the mother as soon as rabies is found to have developed. The milk should never be used for human consumption. So far, all attempts to produce rabies in experimental animals by feeding them the meat of animals dead of rabies have failed. The virus from the brain mixed with food has in some instances produced rabies experimentally. Rabies has been produced in mice by feeding them rabic brain mixed with their food.

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FARM BUTTER MAKING

BY

H. M. BAINER

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FARM BUTTER MAKING

By H. M. BAINER

Looking at farm butter making from a business standpoint, every farmer or dairyman who keeps cows for the butter product, desires to make as much and as good butter as possible. There are many factors which are likely to produce a second or third grade of butter, these must all be taken care of as they come. The majority of dairymen are beginning to realize that good butter is made only from good cream. The churned butter cannot be better than the cream from which it is made. This bulletin is written with the idea of giving general information or directions for making a better grade of farm or ranch butter.

THE DAIRY.

It is generally understood that the kitchen is not a good room in which to ripen and churn the cream.

A good clean cellar, which is well drained, properly lighted

Fig 1—Cement Block Dairy.

and well ventilated is far superior to the kitchen. A separate room, next to the kitchen, with an outside as well as an inside entrance is desirable, if used for dairy work only. There are very few farmers or small dairymen who feel able to construct a separate dairy, although it is desirable.

Such a building can be easily and cheaply constructed of solid concrete walls or cement blocks, as shown in Fig. 1. Any farmer who understands handling cement and can make good forms or molds for construction can make a good solid wall concrete dairy very cheaply. The walls can be made of solid concrete, 4 to 6 inches thick and plastered on the inside with a cement plaster. An excellent wall can be made out of a mixture of 1 part Portland cement, 3 parts sand and 3 parts of gravel, plastered on the inside with a mixture of 1 part cement to 2 parts of sand. The mixture should be placed in the forms in a very wet or sloppy condition. Old barbed wire, or wire of any kind, placed in the walls as they are being constructed, will strengthen them very much, especially at the corners. The floor in the dairy room should be constructed out of concrete, with a cement surface.

The separate dairy should be located so that it is handy to both the house and the barn, so that hot and cold water can be easily secured, and so that it can be well drained. It is advisable to place it near the well so that cold water can be easily secured for cooling the milk or cream. It is a good plan to arrange the dairy so that all water which is pumped for live stock has to pass through a cement tank in the dairy and out through an overflow pipe into the watering trough or supply tank.

Usually a building 10x12 feet, clear on the inside, will be large enough for the average farm dairy.

CLEANLINESS A NECESSITY.

If good butter is to be produced, the milk and cream must be properly handled. The milk cannot be produced under unsanitary conditions and at the same time furnish the raw material for a good quality of butter. The reasons for a poor grade of butter are more frequently found before the milk has been skimmed than after.

The cows should be kept in a healthy condition. The stable should be well lighted, properly drained and thoroughly ventilated. The milker should remember that milk takes on odors very readily and that undesirable bacteria and filth which are allowed to get into it during the milking period, even in apparently small quantities are likely to spoil the product. Some of the greatest sources of contamination are the cows, the milker, the stable, the flies, the pails, strainer, and the stable air. The dark, unventilated, damp stable is the home of disease and germs. On the other hand, plenty of sunlight and fresh air is conducive to health and sure death to most germs. Everything that falls into the milk, flies, hair, particles of dirt, etc., carries with it thousands of bacteria, the majority of these being detrimental. Every possible precaution should be exercised to keep the milk clean and pure. All dirt should be

brushed from the cow before starting to milk and it is often advisable to wipe the udder with a damp cloth. The milker should be clean. The cows should not be fed before milking as it will raise a dust which will help carry bacteria into the milk. The milk should not be allowed to stand in the stable any longer than is absolutely necessary, it should be removed to the dairy room as soon as possible and there strained for the creaming process.

Poor feed, such as musty hay, damaged grain, rotten silage, fermented feeds, etc., will give the milk and butter a bad flavor. Again, certain weeds in the pasture, such as wild onions, ragweeds, etc., will produce bad flavors. Poor water for the cows also has its effect.

THE DAIRY UTENSILS.

All pails and cans should be made of a good grade of tin. They should be made of pressed tin or should have the seams smoothly soldered over, so there will be no places for dirt to lodge. Galvanized and wooden pails are not advisable. The tinware should not be allowed to rust and, above all, it should not be used for any other purpose.

All dairy utensils, including pails, cans, separators, churns, etc., should be thoroughly washed every time after using. They should be first washed or rinsed in cold or luke warm water, not hot, as it will cook the milk onto the tin. After rinsing, wash them in hot water, then thoroughly scald with boiling water or steam and place in the direct rays of the sun. It is not advisable to dry them with a cloth, as they will remain cleaner, if scalded and allowed to drain in the sunlight. Do not use laundry soap in washing the dairy utensils but rather a good washing powder or sal-soda which contains no grease.

SKIMMING THE MILK.

There are two general systems of separating the cream from the skim milk: The centrifugal or hand separator method and the gravity or setting method. The gravity method being again divided into three divisions; namely, deep setting, shallow pan and water dilution. Taking these all together there are four general methods.

Briefly summarized we give the following statements concerning each method:

Hand Separator.—This method is, by far, the best. The relative skimming efficiency of the hand separator and gravity systems as determined by experiments at the Purdue Agricultural Experiment Station showing the per cent. of butter fat in the skim milk are as follows:

Hand separator .02%.

Deep setting .17%, 8½ times the hand separator.

Shallow pan .44%, 22 times the hand separator.
Water dilution .68%, 34 times the hand separator.

Not only does the hand separator secure practically all of the butter fat, but it delivers the skim milk in a sweet, warm and undiluted condition ready to be fed to the calves or pigs. Fewer dairy utensils are needed, as the milk is separated as soon as it comes from the cow and the skim milk is fed at once.

Less work is required to handle the milk in this method than in others.

The cream delivered from the separator is of uniform richness with much of the fibrous and foreign matter removed. About 50%

Fig. 2—Hand Separator Ready for Skimming.

of the total number of germs found in the milk are thrown out by the separator into the bowl slime.

The milk has had less chance to absorp bad flavors and odors from standing around and the cream is produced in excellent condition. By using the hand separator, there is a gain in the quality as well as the quantity of butter obtained.

Deep Setting.—In this method, the warm milk is strained into a can, usually of the shot gun type, which is tall and of small diameter. This is set into a tub or trough and is surrounded with cold water. The milk is usually allowed to set for 24 hours, at

the end of which time the skim milk is drawn off through a faucet at the bottom, leaving the cream in the bottom of the can. Often the can is not provided with a faucet and the cream is removed from the surface with a saucer or hand skimmer. Generally, the deep setting system produces a better grade of cream than either the shallow pan or water dilution systems. The cream is usually removed in a sweet condition, less surface is exposed to the drying action of the air and the skim milk is in better condition for feeding, although it is cold and sometimes sour. The cream is not of uniform richness and is often not rich enough to churn well.

Shallow Pan.—The milk is strained into pans or crocks and is set in a cool place to cream out. It is sometimes set in cold water. It requires about 36 hours setting and is then skimmed from the surface. Usually the cream and skim milk is sour. The cream is not of uniform richness, and is often leathery and of a poor quality.

Water Dilution.—The milk is strained into a special can and is usually diluted with equal parts of cold water. It is set for 12 hours and then skimmed by drawing off through a faucet at the bottom. This method is poorest of all. Often as high as one-fourth of all the butter fat is lost. The skim milk is very poor. The calf has to drink two gallons to get one gallon of milk. The cream is thin, it has a watery flavor and is often very much contaminated with the impurities of the water.

The water dilution separator must be considered as a failure.

The farmer who handles the milk from 10 cows which produce 80,000 pounds of milk per year, should not lose over 30 pounds of butter fat in hand separator skim milk. By good use of the gravity methods he would lose from 275 to 600 pounds of butter fat in the skim milk. To be sure this is not all lost, especially when fed to calves or hogs, but the same food element can be much more cheaply supplied, in corn, kafir, or milo.

SELECTING THE SEPARATOR.

There are many makes of good separators now found on the market which are sold as cheaply as many of the poorer makes.

Select a "Standard" machine, one that has a good recommendation and is known to be durable and reliable. Buy a well known machine, one that is guaranteed in construction, material and clean skimming.

Size of Separator.—Hand separators may be procured in sizes varying in capacity from 150 pounds of milk per hour (18 gallons), to 1,200 pounds per hour (144 gallons). The prices vary from about $35.00 for the smaller size to $165.00 for the larger size.

Select a separator with a capacity of not less than 50 pounds per hour for each cow milked. A 10-cow herd would then require

a 500 pound capacity machine and an 18-cow herd a 900 pound capacity one. Don't make the mistake of getting a machine that is too small, as it will take too much time to skim the milk.

COLLECTING THE CHURNING.

Cream should be churned at least twice a week during cold weather and three times a week during warm weather. The frequency of churning will depend largely upon the conditions under which the cream is collected and kept. Enough has been said to show that the kitchen is not the proper place in which to collect and keep cream, although it may be necessary, at times, to take it there for ripening.

As soon as the milk has been skimmed, the cream should be cooled by setting it in a cold place or by running cold water around it. It should be kept in as nearly sweet condition as possible until enough has been gathered for churning. After thoroughly cooling each skimming of cream, it can be added to the previous skimming. In no case should warm cream be added to cold cream, both should be equally cold and then they may be put together and thoroughly mixed. Every time a new skimming of cream is added to that already gathered it should be thoroughly stirred into the cream below. None of the cream should be allowed to stick to the sides of the cream can or jar above the surface.

Do not add fresh cream to a batch of older gathered cream later than twelve or sixteen hours before churning, as it will not ripen or churn uniformly.

A refrigerator is a poor place in which to keep cream which is being collected for a churning. In the first place, it is usually used for keeping a little of everything and a mixture of odors are found in it, which will flavor the butter and at the same time give it a characteristic refrigerator aroma. Again, the refrigerator does not contain enough pure air for cream. About as good a method as any, is to place the cream can in a tank of cold water and give it plenty of pure fresh air. Keep the cream as cold as your well water until within about 12 hours of churning time when it may have to be warmed somewhat for ripening.

RIPENING THE CREAM.

In order to ripen cream, the temperature must be made favorable to the development of the lactic acid bacteria (those that produce the lactic acid or sour the cream). This temperature is usually somewhat above 60° F. The object of ripening or souring the cream is to produce the flavor and aroma in the the butter, to make the cream churn easier and to improve the keeping qualities of the butter. The process of ripening largely controls the quality of the butter, therefore it must be considered as the most important step in farm butter making.

Cream that has been gathered by the gravity methods, instead of the hand separator will need but very little ripening, and will usually not need a starter as it will be sour enough by the time a churning has been collected. It must be frequently stirred, however, during the gathering period to insure its ripening uniformly throughout.

Separator cream, properly collected and cared for will in most cases be practically sweet at the time when enough has been gathered for a churning.

Under creamery conditions, in order to quickly ripen cream and to be sure that the right kind of bacteria are in it, what is known as a starter is added. This starter is nothing more than milk which has been properly soured and kept in good condition and is added to the sweet cream in small quantity. This not only adds the right kind of bacteria for souring the cream but also gives the butter maker control of the fermentation process and he is able to make a uniform grade of butter out of several batches of cream.

Under farm conditions, where the milk is under the control of the butter maker from the beginning, starters are seldom necessary. In fact, to keep a good starter under farm conditions of churning two and three times a week, is a difficult proposition. For farm conditions, the starter cannot be generally recommended, although there may be times when they are necessary. For example, it may be necessary in winter months to add a starter in order to hurry up the ripening process, or to head off the action of numerous undesirable bacteria.

The starter may be good skim milk or whole milk which has been soured under favorable conditions, or it may be ripened cream or butter milk from the previous churning. The starter must be kept in a cool place after it has been properly soured, until used. It should not be allowed to get old or stale, or it will be worse than none. One quart of starter thoroughly mixed with six or eight gallons of cream which has been warmed to from 65° to 75° F. should cause it to properly ripen in 12 hours.

As soon as the cream has become properly ripened, it should be cooled to the churning temperature. The farm butter maker must judge the degree of ripeness by the taste, aroma and appearance. Too sour cream makes a strong flavored butter with poor keeping qualities, in fact, it produces a poorer butter than cream that is not sour enough.

THE CHURNING PROCESS.

The Churn.—One of the best types of farm churns is that with no inside fixtures, such as the barrel churn. Those churns with inside fixtures, agitate the cream in a different way and have more

of a tendency to spoil the grain of the butter, they are also harder to keep clean.

At present, there are several churns on the market that are guaranteed to get the butter out of the cream in from three to eight minutes, these must be considered as frauds. They always spoil the grain of the butter and at the same time partly emulsify or mix the butter fat and milk in such a way as to make them inseparable, thus producing a salvy or grainless butter of very poor keeping quality.

For dairies, making 75 pounds or more of butter per week, there is no doubt but that the small combined churn and worker

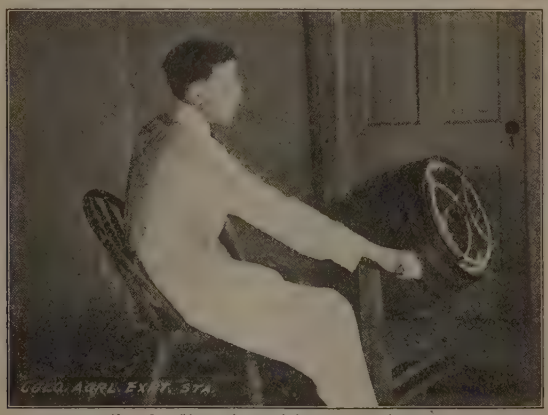

Fig. 3—Churning with Barrel Churn.

will prove more satisfactory than the churn and worker separate. The combined churn and worker is used altogether in creamery practice.

A common error is made in securing churns that are too small. The churn should never be filled more than half full of cream and one-third full is better.

Temperature.—Every butter maker should secure a good dairy thermometer and then use it. One of the main causes for having to churn from one to several hours, is that the cream is not at the right temperature. With a temperature of from 52° to 60° F., butter should be produced in from 25 to 40 minutes, providing the other conditions are right.

After the cream has been ripened it should be cooled to the churning temperature and then held at that temperature from one to three hours before churning.

Churning.—The churn should be first scalded and then thoroughly cooled with cold water.

It is very important that all cream be strained into the churn. This will remove all clots and particles or curd and there will be less danger of white specks in the butter. It is not uncommon to find flies, solid impurities, etc., in the cream, even if handled with the best of care.

Do not fill the churn much over one-third full, but rather give the cream room for agitation, which helps to insure quick churning. Turn the churn just fast enough to give the cream the greatest amount of agitation. In case a barrel churn is used, turn it so the cream has time to fall from one end of the churn to the other, with a distinct thud.

Coloring.—In order to make a uniformly colored butter for the entire year, some color must necessarily be used. Very little will be required during the spring and summer months when the cows are getting green feed. During the fall and winter months more color will be required. No harm is done by moderately coloring butter with a good standard color, of which there are several brands on the market. Colored butter can be sold for a

Fig. 4—Taking Washed Butter from the Churn in Granular Condition.

very much better price than that not colored. White butter is not nearly so appetizing and good in appearance as that which contains color.

The color should be added to the cream in the churn before starting to churn.

When to Stop Churning.—The old practice of churning until all the butter has gathered in one body in the butter milk cannot be considered a good one. In this way too much butter milk is mixed into the butter which cannot be worked out or washed out, this not

only gives the butter a poor flavor but poor keeping qualities as well.

The butter should be gathered until the granules become about the size of a grain of wheat. Then draw off the butter milk through a strainer and wash the butter. If the butter is gathered in larger grains or chunks it will be found harder to properly salt, and at the

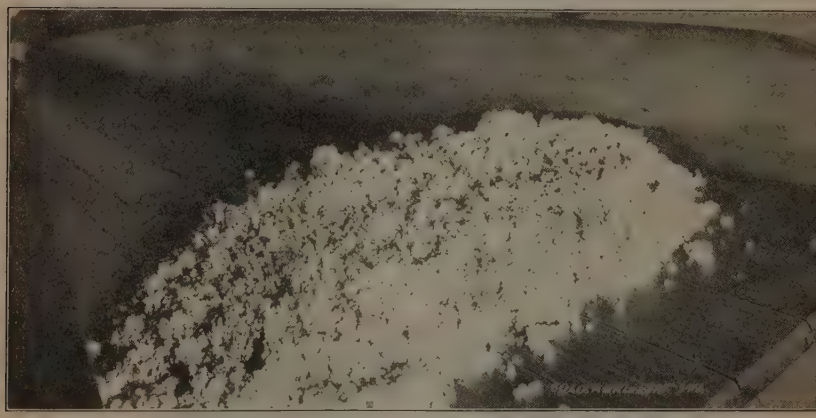

Fig. 5 – Butter on Table Worker just from the Churn. Note Fine Granular Condition.

same time there will be more danger of mottled or spotted butter. It is generally understood that an uneven distribution of salt is largely responsible for mottled butter.

Washing the Butter.—After thoroughly drawing off the butter milk, the butter should be washed in good clean and pure well or spring water. Under good churning conditions, the temperature of the wash water should be about the same as the butter milk. If the butter comes too soft, use water that is colder and if it is too hard, use water slightly warmer.

Pour the wash water into the churn over the butter and turn the churn but four or five quick revolutions. Then draw off the first wash water and put on the second and turn churn as before. If the butter is hard enough after the second washing, draw off the water at once and the butter is ready for salting.

Salting and Working.—If the butter has to be salted and worked outside of the churn, it should be taken out in the granular condition and the salt should be added before it has been worked at all. Nothing but a good grade of dairy salt should be used. As a general rule, about one ounce of salt is added for each pound of the granular butter. The salt should be worked through the

butter with a ladle or some good type of worker and not with the hands.

The best way to work butter outside of the combined churn is by use of the small table worker. Next to this, is the butter bowl and ladle.

Fig 6 —Working Butter in Butter Bowl.

One working, at the time of salting, is usually sufficient, providing the butter is hard enough when removed from the churn and providing, also, that it is worked in a cool place. If the butter

Fig. 7—Working Butter on Table Worker, a Better Method than with Butter Bowl.

becomes too soft before the process of working is completed, it can be set away in a clean, cool place for a short time, until it gets hard enough to finish.

The butter maker will have to judge by taste, distribution of salt, and general appearance, when the butter has been worked enough. Butter has usually been worked enough when the salt is evenly distributed and when the water has been sufficiently removed so that the butter will bend without breaking, when rolled. Too much working will spoil the grain of the butter and make it salvy; while leaving too much water in it will tend to spoil its keeping qualities.

Printing.—Butter should be packed or printed as soon as it has been worked sufficiently, after which it should be put in a cool place until taken to the market.

The appearance of the package, as well as the way the butter is printed or packed, has a great deal to do with the selling price.

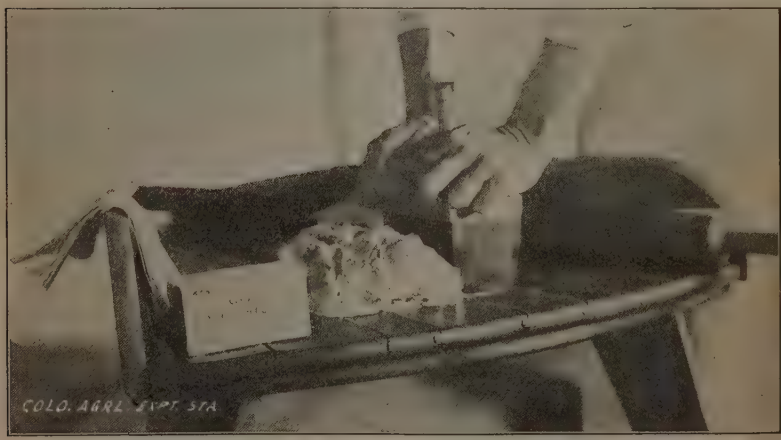

Fig. 8—Printing Worked Butter in 1-lb. Bricks. Note Parchment Paper Wrapper.

The country roll must be considered a thing of the past. The one pound brick print which stamps the name or brand of the maker in the surface of the butter is one of the most popular types of package. Instead of this, it may be better to put up the plain pound print and wrap it with a printed parchment paper which shows the name of the maker and the brand or quality on the outside.

WHY DO I HAVE TO CHURN SO LONG?

1.—The cream should be churned at a temperature of 52° to 60° F. depending on the time of year and the room temperature.

In winter this temperature may run from 57° to 60°, especially if the room in which the churning is done is cool. In summer the temperature should be somewhat cooler, 52° to 57°, especially if the room is warm. If the cream is too cold, it will foam and expand, and sometimes the churn will get too full. When this takes place little can be done, except to allow the cream to stand for sometime, or to warm it gradually four or five degrees before starting to churn again. There is less danger of the cream foaming in revolving churns, such as the barrel churn, than there is with the dash churn, or almost any other class of churns.

2.—The cream may be too old. It should be churned at least twice per week, even in winter.

3.—The cream may not be perfectly ripened. (See "Ripening the Cream").

4.—The individual cows of the dairy may have been milked for a long period without new cows having been added to the herd. The butter fat globules become smaller as the period of lactation advances. The smaller the fat globules become, the longer it is necessary to churn.

5.—When cows are taken off grass and fed dry feed, it often has the effect of making it necessary to churn longer. This may be overcome, somewhat, by feeding succulent feeds, such as silage and roots.

6.—Often the butter will collect in the churn in very fine grains, and further churning seems to do but very little good. Under these conditions, the butter can usually be made to gather by diluting the cream with a small amount of water at the churning temperature. It may also be overcome by adding a handful of salt to the cream in the churn. The solution of the salt affects the viscosity of the cream in such a way as to hasten the formation of butter fat globules.

SUMMARY.

Good butter can be made from good cream only.

The kitchen is not a good room in which to ripen and churn the cream.

The dairy should be arranged so that all water which is pumped for live stock has to pass through a cement tank and out through an overflow pipe into the watering trough or supply tank.

The cows should be kept and milked under sanitary conditions.

The milk should not be allowed to stand in the stable longer than is absolutely necessary.

Poor feed, weeds, and poor water will give the milk and butter a bad flavor.

Of the different methods of skimming milk, the hand separa-

tor is best; deep setting, second; shallow pan method, third, and water dilution, fourth.

Do not add warm cream to cold cream. Keep the cream thoroughly stirred, especially while it is being ripened.

The process of ripening, largely controls the quality of the butter, therefore it must be considered as the most important step in farm butter making

The barrel churn is a very good farm churn.

From 25 to 40 minutes is about the proper length of time to churn.

Strain all cream into the churn.

To properly color butter, add the coloring to the cream in the churn just before starting to churn.

Stop churning when the butter fat granules become the size of a grain of wheat.

It pays to wash the butter.

Too much working will spoil the grain of the butter and make it salvy; while leaving too much water in it will tend to spoil its keeping qualities.

The good butter maker will place his name and brand on his product.

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POULTRY RAISING

BY

W. E. VAPLON

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POULTRY RAISING

By W. E. VAPLON

The call for information relative to conditions for successful poultry raising in Colorado has become so great that it seems necessary to issue a bulletin of general information which can be sent in answer to inquiries.

The information here given is not the result of experimentation on the College farm, but of several months of investigation reaching to all parts of our State among expert poultrymen, added to the experience of fifteen years' work with poultry in Colorado by the writer.

While we hope this bulletin will be an encouragement to those expecting to raise poultry on a commercial scale, we also hope that it may disillusionize some who are being carried away by fables of immense profits derived by using get-rich-quick systems. Enthusiasm is a splendid factor in poultry raising, but should be tempered with knowledge.

LOCATION OF THE POULTRY FARM.

In discussing the matter of choosing a location for a poultry farm, we are not considering the farmer who is already established on his land, and to whom the hen is only a side issue, but rather the man or woman who is intending to make poultry raising or egg production the means of livelihood. Success may, and often does depend upon location, and once decided upon, a change is not easily made. In the choice of a location the following factors should be carefully considered;

Nearness to market.
Character of soil.
Water supply.
Convenience.
Cost of land.

Nearness to Market.—To produce large numbers of eggs is only half of the poultryman's problem, he must be able to market his products cheaply at a good average price to make a profit, hence nearness to market, or good transportation facilities, are important considerations. The Colorado poultryman is very fortunate as to markets, as it is doubtful if there is a community in the State which furnishes its own poultry products for the entire year. Our mining towns, health re-

sorts and large cities are entirely dependent upon outside sources for their supply. About four millions of dollars' worth of poultry products are shipped into Colorado annually, and every dollars' worth should be produced at home. This means that practically all the output of our silver mines goes to neighboring states for poultry products.

Character of the Soil.—While it is true that poultry will do well on any of our soils, it is also true that soils best adapted to general farm crops give best results to the poultryman. The soil should be porous enough to dry off quickly after a rain, but heavy enough to produce good crops of vegetables, alfalfa, grain, berries or any crop desired, these crops to be used for the poultry, or as added sources of income. This character of soil can be kept cultivated with less labor than heavy clay soil, thus insuring clean, sweet range for the fowls. While it may be true that grain can be bought as cheaply as it can be raised, we believe that it would be advisable to grow some of the grain used if possible, if only for the added value of the straw thus produced. We find that our poultrymen are inclined to be rather chary in the matter of litter for their fowls, as one will naturally be where straw is as expensive as it is in some portions of our State. Especially if the land is level should it be somewhat sandy, as heavy clay soil, when frequently wet, soon becomes filthy by reason of becoming packed.

A south slope is ideal on account of drainage and sunny exposure. A north slope is undesirable and wet land should never be considered.

Water Supply.—No other water system can equal a living stream or spring, and if the fowls can help themselves at will, so much the better for them and for their keeper also. Every device or convenience that lessens labor, especially if it costs little or nothing, means so much more profit, and carrying water to a large number of fowls is certainly very expensive by reason of the time and labor consumed. Where water is furnished, cleanliness should be carefully observed. Galvanized iron or stoneware drinking vessels are preferable. Wooden troughs are objectionable because they furnish lodgment for disease germs. The water dishes should be kept clean, and be frequently replenished with fresh water. During warm weather the water should be kept in a shady place to keep it as cool as possible.

Convenient Arrangement.—In all the work of selecting a location, building, fencing, etc., the matter of convenience should never be lost sight of. The relation of each building to all the others, to the roads and highways, and to the residence, should be very carefully considered. Convenience means a saving of time and labor, which means added profits. The usual way of building each new poultry house in the most convenient place left vacant, without refer-

ence to those that may follow, will mean many unnecessary steps, discomfort and dissatisfaction. Lay out your plant as though you expected at some future time to have your entire farm, whether large or small, devoted to poultry. Whether you expand to such proportions or not, if you have planned wisely, you will be saved much annoyance and labor and your work will be better done.

Cost of Land.—How much to pay for land must depend largely upon the object in mind in engaging in poultry raising.

If the intention is to supply both poultry and eggs to the consumer, thus necessitating weekly or semi-weekly trips, it would be advisable to pay more for land in order to get nearer to market, and use less acreage. Time is money, and long drives take time. On the other hand if the intention is to wholesale the products, and make eggs the primary object, or perhaps to employ the colony system of housing, it would be advisable to buy cheaper land farther from market and ship the products by train. With daily mails, telephones and fast trains, one can easily keep in touch with the markets; and while the prices received would be less than in retailing, the cost of production and delivery would also be less, and the net profit would perhaps be about the same.

BREEDS.

We have no space to take up the history of our various breeds. We wish to aid the beginner to choose the right breed of fowls for his or her special purpose, and from a commercial standpoint the choice necessarily falls upon the so-called "general-purpose" fowls, commonly classified as the American breeds, or upon the so-called "egg breeds"—the Mediterraneans and other smaller fowls.

General Purpose Breeds.—Under this head will come the different varieties of Plymouth Rocks, the Wyandottes, the Rhode Island Reds, and the Orpingtons. These breeds are spoken of as "general purpose" because they answer the call for a fowl which will give the owner an early broiler, a plump, good-sized roaster, and also a goodly number of eggs in the course of a year. Where the intention is to furnish both eggs and fowls for the market, and especially where one can sell directly to the consumer, no mistake can be made in selecting any variety of any of these breeds. Perhaps the variety chosen should be the one most nearly pleasing the fancy of the individual.

Egg Breeds.—Almost invariably where "eggs for the market" is the principal object of the poultryman, one of the smaller breeds is chosen, and usually the Single Comb White Leghorn is the variety. Often where the object is "eggs and broilers" the same variety is chosen, as the chicks come to broiler size, one to one and a half pounds, nearly as quickly as the larger breeds.

For roasters they are found wanting, nor do we believe it will pay to raise any chicken to roaster size in Colorado until our markets will pay as much per pound for a roaster as for a broiler. As it is now, a broiler worth fifty cents will bring no more if kept to twice the size and weight at an added expense and risk, and sold as a roaster. Our poultry raisers are mostly to blame for this, as no attempt is made to finish their products nor to educate the consumer's taste to the toothsomeness of a fine, plump, specially fattened roaster.

Other varieties of Leghorns, the Brown and Buff especially, are quite popular in certain localities and furnish the same white egg and yellow carcass as the White. The Minorcas and Black Spanish, Anconas, Hamburgs, Polish, and many others might be mentioned as belonging to this class or type, but on a large scale from a commercial standpoint, a beginner had better stick to the better known and more popular varieties.

Meat Breeds.—The feather-legged Asiatics, the Langshans, Cochins, and Brahmas, weighing when mature seven to twelve pounds, are generally classed under this head. In the East, where large roasters and capons are in demand at certain seasons at good prices, these varieties are profitably raised for their flesh, but the reason we gave in the preceding paragraph for not raising poultry in our state for the flesh, will bar these larger breeds for the present from our commercial poultry farms.

Choosing a Breed.—Until our people wake up to the great possibilities of poultry keeping in Colorado, the advantages of soil, sunshine, foods and markets, that we possess; and until each community produces more than it consumes, and has a considerable amount to send out, the matter of choosing a breed is very much a matter of personal preference; but when Colorado as a State produces eggs and poultry for export, we must make choice of a breed or variety that will produce a uniform product in order to get the best prices.

FEEDING.

A hen craves and seeks a variety of food, and must have it to be healthy and profitable. If the hen has free-range, grain is all that need be provided during the summer, as she can find sufficient vegetable and animal foods. In the winter, and also if confined in summer, everything must be provided. The nearer we can come to providing just the right proportion of these foods, the nearer we come to an economical and balanced ration.

Hopper Feeding.—It woud be easy to provide a balanced ration by giving her free access to hoppers containing all these different foods, but we must not forget the matter of exercise. On free range,

a hen will seldom overeat of grain, even if it is kept before her all the time. Hunting worms, bugs, grasshoppers, etc. affords her the necessary exercise to keep her in good condition; but in close confinement, especially in cold weather, exercise should be provided as carefully as food. Confinement does not hurt the hen, it is really much better during cold and stormy weather than freedom, but she must have something to do. Every inch of the floor space should be clear for her use, covered deep with straw or other clean litter, and all grains should be scattered in this to induce scratching. A busy hen is a healthy hen, and only a healthy hen is profitable.

Grains.—All grains are good, but a steady diet of any one grain is neither good nor economical. Where milo and Indian corn can be most successfully grown, these can be made the principal grain feed, but a hopper of dry bran kept before the fowls all the time and occasionally a feed of wheat or oats, even if comparatively high in price, will be found beneficial and economical. Cooked beans and cracked peas are a splendid addition to the grains and are cheaply grown. In most sections of Colorado, however, wheat, corn and oats will be found cheap enough to use largely, and a poultryman will find that it will pay well to lay in a winter's supply of wheat and oats at threshing time, as the price usually advances twenty-five per cent. or more later in the season.

Animal Food.—Something should be provided to take the place of the worms and insects so relished by the hen on free range. Green bone and meat scraps from the butcher, and blood meal from the packing house, the flesh and bones of any farm animal, all are rich in those elements necessary for growth and for egg production. An old cow, no longer profitable for milk production, may be worth more as egg material than for beef, and a horse worn out or crippled will make the finest addition to the grains. Fresh cut bone and beef scraps can usually be procured at a fair price, but where meat is not easily obtained and the prepared foods are expensive, milk in some form will be found to be a satisfactory substitute.

Green Foods.—During the winter if the fowls are confined, we are apt to overfeed with the grains, and under feed with the more succulent vegetable foods. Alfalfa leaves, either dry or steamed, make as good a green food as we can furnish. So good is it, that eastern poultrymen are paying as high as $65 per ton for cut alfalfa, which is not as good as the leaves, as all the hay is used in making it. Any of the root crops, sugar or stock beets, turnips or carrots, cabbage, potatoes, onions, waste apples, would be equally welcome and beneficial to the fowls.

It pays to keep a supply of grit, oyster shell and charcoal before

the fowls. The more you can coax your laying hen to eat and assimilate, the more material will she have to turn into eggs. Her body must be nourished and material supplied for eggs. To provide for both purposes during cold weather means grinding up a great deal of food. The grit helps to do this and the oyster shell furnishes material for the egg shell. Charcoal furnishes no nourishment but promotes digestion, and is a bowel corrective.

Nutritive Ratio.—A poultryman should know the approximate food value of his feeding stuffs in order to supply the necessary nutrients at the least cost. No one has yet proven the superior value of wet or dry mash, and whether or not you keep a hopper of dry, ground grains before your fowls, they will occasionally relish a moist, steamed mash of vegetables and ground grain, seasoned as you would like it for yourself. Let the morning meal in winter be cracked grain of some kind in the litter, and feed the mash either at noon or in the evening, and never more than they will clean up. We have as yet found nothing more gratifying to our fowls for supper than corn, either whole or cracked, and this should be fed in clean straw, or in such a manner that the fowls must use some energy in digging it out. When you find your hens becoming anxious for their meals is the time to feed rather than at some fixed hour.

Feeding Chicks.—What we have said about feeding fowls can be applied to the chicks, when they get hungry do not withhold food because a certain time has not elapsed. Some of the brood will eat very heartily, some not at all and a little prepared chick feed, rolled oats, bread crumbs moistened with milk, or a hard boiled egg, will certainly do no hurt to the hungry chick. It may be possible to raise them without water, as some advocate, but we cannot understand how anyone who has ever seen the little fellows pile into a water dish can withold this from them; so provide cool, clean water and milk in any form in clean dishes. What applies to the hen applies also to the chickens, variety and plenty with exercise. For a few days the chicks should be fed regularly, after that much time and labor may be saved by having plenty of cracked grain in fine litter (alfalfa leaves are good) where the chicks can get it at any time.

Bear in mind in poultry raising that cleanliness is one of the necessary factors for success. Cleanliness of buildings and coops means freedom from vermin. Cleanliness of yards and runs will be a more or less difficult matter depending upon how your plant has been arranged and upon your methods of housing and yarding. When many fowls and chicks are kept on a small acreage, frequent turning up of fresh earth is essential to cleanliness. To do this by hand is a very difficult job, so have the yards and runs of such size and shape that a horse can be used.

Cleanliness of water dishes, food troughs and nest boxes is also important. Get the habit of cleanliness and you need not fear poultry diseases.

INCUBATION.

The beginner can profitably follow both methods of incubation, the hen and the incubator. The production of strong, thrifty chicks depends upon other factors than the broody hen or the make of incubator used. As long as we follow the common practice of helping the chicks from the shell when they do not want to be hatched, compelling them to live by the use of flannels and soothing syrup when they wish to die, calling in the doctor whenever the growing chick or the hen has the colic, using roup and cholera and all the other "cures"; just so long will we have eggs of weak fertility and the same incubation difficulties.

Hatching with Incubators.—The beginner should follow closely the instructions sent with the machine he is using. It will be time enough to disregard the rules when experience has proven something else better. There are many different makes proving good in our state and we would advise buying the machine doing well in your own community. Do not hatch more chicks than you can well care for, but hatch your season's crop in as short a time as possible. To do this where many chicks are wanted will require large incubator capacity, but it will be found advisable not to prolong the hatching season unless broilers are turned off regularly. In this way the broods will be larger and fewer, the chicks will be of more uniform size, therefore more thrifty, and the poultryman will be able to devote more time to other work and thereby lessen the cost of labor.

Hatching with Hens.—The relative merits and advantages of natural and artifical incubation would not be altered by our discussion. Each method has advantages under certain conditions, and some poultrymen under their own peculiar conditions succeed with one method where failure results from trying the other.

Early in the season, when few hens are broody, the incubator will be found necessary to produce early chicks; later the hens will give good results if given good care.

Where to Set.—One of our poultrymen, for over thirty years raising poultry in Colorado, builds his nests tier upon tier along the wall of a small room. Each hen has a nest about a foot square and is fastened in. Every day at a certain time the attendant lifts out a few hens to feed, drink and exercise. When they are ready to return they are carefully lifted in and others are released for a time. To be certain that each hen is returned to her own nest she is banded with a number that corresponds with her nest number. While this means considerable work, this breeder

claims it pays as he has very little trouble with broken eggs, restless hens, etc., and has uniformly good hatches. A row of nests on the floor of an isolated room or building with the center of the floor left free and covered with loose dirt for the use of the hens, is a common and good way of caring for the setting hens. Nests should be about fourteen inches square, ten or twelve inches high, and covered so the hens cannot fight each other when on the eggs. The hen should be allowed to walk into the nest rather than jump down from a height, and loose dirt covered with a little straw or chaff should be placed in the bottom. Remove the setting hen after dark and try her with a few eggs before giving her those for hatching; fasten her in securely; in the morning lift her out to eat and drink and fasten her in until the second morning; then give her twelve to fifteen eggs and see that she has plenty of fresh water and food, preferably corn. She will probably return to her own nest now and need not be fastened in. Besides a dusting place for the hen she should be thoroughly dusted with prepared lice powder during her time on the nest, but care should be taken not to use too much powder, just a light sprinkling well into the feathers.

Hens, like incubators, should not be disturbed at time of hatching. Some hens will kill their chicks and such should be removed and the eggs given to another if possible. It will not be found profitable to help chicks out of the shell. The breeding stock should have enough vigor to produce eggs that will hatch good lively chicks on time.

Brooders.—The fireless brooder seems very successful and popular with our poultrymen, especially where chicks are kept in heated brooders the first two or three weeks, and are then placed in fireless brooders. This plan works very well where a comparatively small number of chicks are raised, but we would advise beginners to provide heated brooders, and only transfer the chicks to the fireless brooder when large enough to readily go in and out of their own free will, and then have the brooder in a good comfortable building. We believe there will be very little bowel trouble in the little chicks if they are never chilled, and we know the fireless brooder is responsible for many deaths among our chicks on account of chilling. When many chicks are raised a stove heating system should be installed to lessen expense and labor.

Rearing Chicks With Hens.—We do not like to give hens with chicks unlimited range. Certainly for a week or two after the hatch the hen should be confined to her coop or a small run attached to the coop to give the chicks time to gain strength. The chicks can be given their liberty as they will not stray far away from the mother hen. A floor or a platform of boards on which a bottomless coop is placed is necessary on account of heavy showers which are at any time possible, and which often flood the coops and drown the chicks where no floors are provided. A packing case covered with roofing paper, makes a cheap, comfortable coop. Where straw is scarce dry sifted earth makes a good covering for the

floors and should be often replaced, daily after the chicks are two or three weeks old. When two hens hatch at the same time all the chicks can be given to one hen and the other hen can be re-set if she is in good condition. We have found that hens confined to coops give their chicks more brooding, are soon contented with their narrow quarters, and will raise more chicks than when given full liberty.

MARKETING.

Higher cost of living seems to be troubling a great many people just now, yet they are more willing than ever to pay an extra price for quality. Produce a good egg, market only eggs of uniform color and size, send clean eggs in clean, attractive carriers, and get them to the market during the summer at least twice a week.

Marketing Chicks.—Be careful in preparing your chicks and fowls for market. Have them uniform in size and color, the broilers one and a half to two pounds, and the roasters four to five pounds in weight. It pays to give both old and young stock a little special preparation before shipping. Keep in close quarters without exercise for a week before selling, feeding mashes of fattening foods. In supplying a family trade with dressed poultry, it will undoubtedly pay to crate and fatten for a better finish and appearance of the carcass as the extra quality means a better price. The Denver market prefers the yellow skinned fowls, alive.

RECORDS AND ACCOUNTS.

Daily laying records should be carefully kept and if the hens are not doing their duty, the cause should be found and the remedy applied. Perhaps the feeding method can be bettered, or more likely the drones have not all been discovered. Incubation records which will show the fertility of different flocks or pens will help to greater success. Breeding, mortality and feeding records will be found very instructive and helpful to better results.

Poultry raising means dollars and cents, debit and credit, and every poultryman should know his exact financial position at any time. By means of carefully kept accounts of receipts and expenditures, he will be able to know what branch of his business is most profitable or is not paying; where leaks and wastes occur, what branch of his business can be profitably enlarged, and which might better be curtailed.

POULTRY LITERATURE.

Too much value cannot be placed upon good poultry literature, and there is much to be obtained. However, one must be able to read between the lines of much that we find in our poultry journals, as the writers often have an "ax to grind", eggs to sell from the hen that laid 333 eggs in a year, a system or a method.

POULTRY SECRETS.

There are no mysterious poultry secrets which you need to buy in order to succeed in the work. All the so-called "secrets" and "processes" can be procured through experiment stations and government bulletins. It is not the breed, nor the feed, nor the house, nor the care; not any one or two of these factors, but all carefully applied that are necessary to success.

SELECTION AND CULLING.

Continued selection of the best, elimination of the weaklings, eternal cleanliness, comforable shelter, plenty of fresh air, sunshine and exercise, a variety of good nourishing, succulent foods; all thoroughly mixed with love for the work and faith in the hen, seasoned with common sense and business ability; these are the great secrets of success with poultry.

POULTRY BUILDINGS.

We might revive one of Solomon's very wise sayings and make it read: "Of the making of poultry houses there is no end," and perhaps add, "There is nothing new under the sun." Old ideas of poultry house construction are about as regularly revived as styles in hats, answer the demand of a certain class of poultrymen and are condemned by others. Limited space forbids our going into detailed instructions for building. We are giving the matter much thought and attention at the present time, and are trying out five distinct types that have been adopted by successful poultrymen, which are considered about right, and intend to build some other models for comparison. All are good, each has some advantages and some disadvantages. Location, conditions, circumstances, amount of land, price of materials, many factors must necessarily govern the type and size of the buildings.

Reasons for Housing.—The object of the house is to provide shelter for the fowls, and should be wind and rain proof, a single thickness of drop-siding or sheathing with building paper, being sufficient in our climate. Where lumber is used the best is cheapest, and we prefer the four-inch drop siding. Good sheathing, covered or battened will cost as much or more than drop siding, and will never make as tight a wall. Shiplap is not satisfactory as it soon dries out and leaves a crack. Whatever the materials used, have them good. If you must economize do it in the size of the building rather than in the quality of the material. Have your buildings face south, one third or one half of the south end covered with burlap or muslin curtain to be raised whenever the weather will permit, which will be nearly every day in the year. Some glass in the front may be convenient but is not necessary. The burlap curtain will furnish plenty of fresh air when closed, providing all the necessary ventilation. The door should be either in the east

or south, the west and north walls and roof being absolutely tight. We know of quite a number of poultry houses in Colorado facing east or west, but know of no good reason for it, and many against it. You will find no stronger ally in fighting disease and discomfort in your flocks than the sunshine, and the south front, especially in the long house, permits the greatest amount of it. Let it flood the coops and buildings as much as possible.

Comfort and Convenience.—A hen would probably consider a house about three feet high ideal, especially in cold weather, but for the convenience of the caretaker we must build them higher; unnecessary height means a colder and more expensive house, so build as low as possible, consistent with convenience. The farther the roosts are from the open end the better for the fowls—twelve feet is better than less. Make the pen shorter rather than narrower, if you want a certain floor space.

Nests.—Nests placed on the ground outside and against the building, covered with a slanting board to shed the rain, are sometimes very satisfactory. If within the building, they should be above the floor and boxes about fourteen inches square will be found to answer the purpose. They are preferable to expensive lumber nests as they can be destroyed when mites get into them. When trap nests are used, one nest should be provided for each two or three hens, otherwise half the number of nests will be sufficient.

Cost of Building.—It is easy to be extravagant in building. Don't do it. Extravagance and waste are the cause of as many failures as inexperience. Limit the cost of providing house room to sixty dollars for material per hundred hens. It can be done for less, perhaps, but ought not to cost more. A poultryman should be able to do his own building, even if he hires it done. By knowing how, it will be done right and to hire a carpenter for every little job is expensive.

Fixtures.—Have all fixtures such as grit boxes, feed hoppers, water dishes, etc., off the floor. We build our hoppers for grit, charcoal, oyster shell and ground grain, between the 2x4 studding and prefer them to anything we can buy. Have them two feet above the floor so no litter or dirt can get into them. In permanent houses have a platform two feet above the ground across the entire rear of the pens, above which the roosts are placed. This platform catches all the droppings, means less labor in cleaning, and means a clean floor for the hens in bad weather. The water dish can be placed on the edge of this platform.

Roosts.—I see many 2x4 scantlings used for roosts; a 2x2 is better and costs half as much. A round pole is objectionable as it soon splits and the cracks offer a lodging place for mites. Instead of hinging them to the wall, try driving a nail through the 1x2 used to support the roosts, to the upright studding. Your roosts can then be swung up out of the way when cleaning. Have the roosts about ten inches above the platform, and after cleaning, dash a shovel of litter or dirt over the platform which will prevent the droppings sticking and make cleaning easier.

DISEASES.

The Veterinary Department of our College, under the direction of Doctors Glover and Kaupp, is working on poultry diseases at the present time. When their investigations are completed, a bulletin will be published which will be sent to all who send a request for one. Later we expect to publish separate bulletins on buildings, feeding, incubation, etc., to give the results of our experimentations along these lines. In the meantime we will gladly answer any specific questions as far as possible.

RECENT BULLETINS.

The following recent bulletins of the Experiment Station are still available and will be sent, while the supply lasts, to anyone sending his name and address to the experiment station, giving the name or number of the bulletins he especially desires.

No.

43. Colorado Lepidotera. A Few Species of Deltocephalus and Athysanus from Colorado. A list of Original Types etc. in Colorado.
83. Irrigation Waters and Their Effects.
84. An Apricot Blight.
97. Feeding Steers on Sugar Beet Pulp, Alfalfa Hay and Farm Grains.
100. The Flora of Colorado.
108. Development of the Rocky Ford Cantaloupe Industry.
110. Alfalfa—Results Obtained at the Colorado Experiment Station.
122. Fruit Growers' Associations.
124. Colorado Fodders—An Examination into Their Composition and Comparative Values.
125. Colorado Fodders—A Study of Comparative Values Based on Bulletin 124.
127. Climate of Colorado—Temperature—21 Years Record at Fort Collins.
131. Arsenical Poisoning of Fruit Trees.
135. The Australian Salt Bush—Its Composition and Digestibility.
136. Dewberry Growing.
138. Some Bacterial Diseases of Plants.
139. Pruning Mature Fruit Trees.
141. Grape Growing.
142. Tillage, Fertilizers and Shade Crops for Orchards.
143. Cabbage Growing.
144. Celery Growing in Colorado.
146. Raising Hogs in Colorado.
147. Top-Working Fruit Trees.
151. Ration Experiment With Lambs—Self-Feeders for Hay.
149. Carrying Range Steers Through the Winter—Sugar Beets for Fattening Steers.

152. Two Common Orchard Mites—The Brown Mite and the Red Spider.
154. Alfalfa Studies—Third Progress Report.
155. The Fixation of Nitrogen in Some Colorado Soils.
156. Butter Making—Clean Milk and Commercial Starters.
157. Arsenical Poisoning of Fruit Trees.
158. A Bacterial Disease of Alfalfa.
159. A New Alfalfa Disease—Stem Blight.
160. Nitrates in the Soil—An Explanation of so-called "Black Alkali" or "Brown Spots."
161. Cement and Concrete Fence Posts.
162. Rabies.
163. Farm Butter Making.
165. Ration Experiment With Swine.
166. Information Concerning the Carriage Horse Breeding Experiment.

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The Agricultural Experiment Station

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RATION EXPERIMENTS WITH SWINE, 1906--1908

BY

W. L. CARLYLE *and* G. E. MORTON

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RATION EXPERIMENTS WITH SWINE, 1906--1908

W. L. CARLYLE *and* G. E. MORTON

INTRODUCTION

This bulletin records two experiments, the first conducted during the winter of 1906-07, and the second during the winter of 1907-08. Both experiments were planned to discover what protein feeds would prove most economical when fed with barley and with corn. These two grains are the most available and commonly used of any of the feeds used in this State, with the possible exception of field peas. But neither corn nor barley is an economical feed for hogs when fed alone. This is now recognized in the corn belt, after much experimental work by the various experiment stations. Our problem, therefore, is to find what available feeds may be used in this State to best advantage for supplementing these grains.

THE FEEDS SELECTED.

Alfalfa hay, wheat, field peas, wheat shorts, and packing house tankage were the feeds selected because of their availability throughout the State. Wheat shorts consist of the finer particles of bran and a portion of the kernel within the bran. They contain more starch and less crude fibre than bran, and are less bulky. Selected tankage, a packing house product, is made from residue meat scraps, and has a large percentage of protein.

1906--1907 EXPERIMENTS

Ten lots of ten head each were fed. The pigs averaged from 66 to 70 pounds each when they were put on feed. They were Poland China grades, about six or seven months old, bought in the country surrounding Fort Collins. They were very small for their age but of good enough breeding to show fair returns for feed. They were uniform in breeding, age and condition. At the close of thirteen weeks feeding, the lots ranged from an average weight of 154 pounds per head to 200 pounds per head.

The following table gives the results:

TABLE A.

FEED FOR GAIN AND COST OF GAIN, 1906-07

(Ten head in pen.)

PEN NO.	RATION	Gain per Head 13 Weeks. Lbs.	POUNDS FEED FOR 100 POUNDS GAIN				*Cost of Feed for 100 lbs. of Gain	Standing of Lots
			Grain	Hay	Tankage	Beets		
I.	Barley; alfalfa hay at pleasure	107	508	75	...	...	$5.27	5 and 6
II.	Corn; alfalfa hay at pleasure	115	508	76	...	...	$5.27	
III.	Barley and corn, equal parts; alfalfa hay at pleasure	131	435	67	...	...	$4.52	1
IV.	Barley one part; wheat one part	115	476	..	...	...	$5.95	7
V.	Barley one part; peas one part	111	482	..	...	...	$7.23	10
VI.	Barley one part; shorts one part	117	457	..	...	...	$4.57	2
VII.	Barley ten parts; tankage one part	130	405	..	46	...	$4.97	4
VIII.	Corn ten parts; tankage one part	142	386	..	42	...	$4.70	3
IX.	Barley; beets at pleasure	94	475	..	...	478	$5.95	8
X.	Corn; beets at pleasure	86	544	..	...	498	$6.69	9

* Note—Prices of feeds figured as follows:
Grain, one cent per pound, except wheat 1½ cent and peas 2 cents.
Tankage, at $40.00 per ton.
Beets, at $5.00 per ton.
Alfalfa, at $5.00 per ton.

POUNDS FEED FOR ONE HUNDRED POUNDS GAIN.

The number of pounds of feed required to produce one hundred pounds of gain in live weight is the point of chief interest to the feeder, and it is probably the best comparative method of stating our results from the experiment. So we depend upon this column chiefly for our conclusions.

SUGAR BEETS WITH GRAIN.

Lots IX and X were fed sugar beets with barley and with corn respectively. It will be noticed that each of these lots consumed about as much grain for each one hundred pounds of gain as did the lots fed grain alone, and in addition they consumed about as much beets as grain, making the ration very expensive. Practically no returns were secured from the beets. It is true that these lots ate about one-fifth less grain during the entire period of feeding than the lots not fed beets; but they also gained very much less in live weight as the foregoing Table "A" shows. They gained only 94 and 86 pounds per head in thirteen weeks, whereas the other lots gained 107 to 142 pounds per head in the same length of time.

And it must be remembered that the beets were not forced

upon the pigs by withholding the grain. The beets were supplied as the pigs desired them. Evidently they relished the succulent feed, and ate enough of it so that they had not the capacity for a quantity of grain sufficient to produce a large gain in live weight.

These results with beets were so marked that it was not thought necessary to duplicate this portion of the experiment another season. And we believe that the conclusion is warranted that for light weight fattening pigs, weighing from 60 to 160 pounds, sugar beets are not an economical fattening feed in connection with grain, when they constitute about half the ration by weight—in this instance all the beets which the pigs would voluntarily eat.

ALFALFA HAY WITH GRAIN.

Lots I, II and III were fed alfalfa hay and grain. Of these, lot III, fed equal parts of barley and corn, did the best, making the heaviest gains, and requiring the least amount of feed for one hundred pounds gain. This lot, in fact, made the best showing of any in the experiment, and figuring the price of the various feeds upon any reasonable basis, the cost of producing pork with this ration of corn, barley, and alfalfa hay, was less than with any other ration used in the experiment.

Lot I, fed barley and alfalfa hay; and lot II, fed corn and alfalfa hay, came out almost equally well, although lot II showed slightly greater gains than lot I. Neither barley and alfalfa hay nor corn and alfalfa hay gave such good results as corn, barley and alfalfa hay, being surpassed in amount of gain produced and in economy of ration, by several rations in the experiment.

COST OF FEED AND STANDING OF LOTS.

In the foregoing Table "A" a column is given showing the cost of the rations with the feeds figured at given prices. One cent per pound will approximate the market prices of barley, corn, and shorts, and is a convenient round number from which an advance or lowering of prices may easily be computed. Peas and wheat are ordinarily higher in price and therefore are figured at two cents and one and a half cents respectively. In looking down the column showing the standing of lots, a series of numbers are found showing the relative order of the rations according to their economy. This column is given only for the purpose of facilitating the finding of the most economical rations.

BARLEY AND WHEAT SHORTS.

It will be seen that after the barley, corn and alfalfa ration, the barley and shorts ration, half and half, was the most economical. There was so little difference, however, in the economy of these two rations that one cannot say either proved better than the other. The

barley, corn and alfalfa lot required 435 pounds of grain and 67 pounds of hay for 100 pounds gain; while the barley and shorts lot required 457 pounds of grain for 100 pounds gain. Both rations were very satisfactory.

GRAIN AND TANKAGE.

Lots VII and VIII were fed barley and tankage, and corn and tankage respectively, ten pounds of grain being fed for each pound of tankage. The corn and tankage produced slightly better results than barley and tankage, and both rations were good, coming next to lots III and VI in point of economy.

BARLEY AND WHEAT, EQUAL PARTS.

This ration gave good gains, and required only 476 pounds of feed for 100 pounds gain in live weight. But with wheat at any ordinary figure, the cost of the ration is high. If cheap wheat can be gotten—that is, wheat at the price of corn or barley, the wheat and barley ration will prove a satisfactory one. Barley offsets the tendency towards production of soft and flabby flesh which wheat favors, and the two together give good gains.

BARLEY AND PEAS, EQUAL PARTS.

This ration is not equal in production of gain to any of the other rations except the beet rations, and one alfalfa hay ration. Also, the amount of feed required for gain was 482 pounds—considerably greater than that required by the other rations in which grain or grain by products only were fed. And since peas are ordinarily higher in price than corn or the small grains, the ration does not prove economical.

This, of course, does not mean that a ration of barley fed to swine hogging off peas in the field might not prove economical. These results apply only to threshed peas when fed with barley to hogs that are confined to feed yards.

The following Table "B" gives the digestible nutrients required for one hundred pounds of gain in live weight. The nutritive ratio shows the proportion of protein to carbo-hydrates and fat in each ration; for example with Lot I, the nutritive ratio is 7.8; that is, there was one pound of protein to every 7.8 pounds of carbo-hydrates and fat in the ration.

TABLE B. (See Table F, in Appendix)

DIGESTIBLE NUTRIENTS REQUIRED FOR 100 LBS. GAIN, ALL PENS

PEN NO.	TOTAL GAIN (Lbs.)	POUNDS OF DIGESTIBLE NUTRIENTS REQUIRED FOR 100 LBS. GAIN			NUTRIENT RATIO
		Protein	Carbo-Hydrates	Ether Extract	
I.	1066	49.51	377.49	9.01	7.8
II.	1145	49.25	366.41	22.18	7.9
III.	1303	42.64	319.12	13.12	7.81
IV.	1153	43.19	328.10	8.08	8.05
V.	1112	62.41	252.43	5.86	4.27
VI.	1168	46.40	273.63	12.65	6.55
VII.	1299	52.19	281.60	12.76	5.98
VIII.	1417	41.78	259.84	21.99	6.40
IX.	940	63.09	690.21	8.98	11.28
X.	863	69.29	741.13	24.36	11.54

1907--1908 EXPERIMENT

Six lots with eight head in each lot were fed during this experiment. They were fed during the same season of the year and were the same class of hogs and of about the same weight as those described in the previous experiment. The experiment lasted fifteen weeks—two weeks longer than the previous winter's experiment. The pigs were of uniform breeding, age, and condition.

The most promising rations, as shown by the previous winter's feeding, were tried again and selected tankage was tried with various grains.

TABLE I.

FEED FOR GAIN AND COST OF GAIN

(Eight pigs in each pen)

PEN NO.	RATION	AV. GAIN PER HEAD, 15 WEEKS. LBS.	POUNDS OF FEED FOR 100 POUNDS GAIN			*COST OF 100 LBS. GAIN	STANDING OF LOTS
			Grain	Tankage	Hay		
1.	Barley three parts, corn three parts, alfalfa hay at pleasure.	116	496	..	56	$5.10	4
2.	Barley three parts, corn three parts, tankage one part	171	338	56	..	$4.50	1
3.	Barley six parts, tankage one part	158	367	61	..	$4.89	3
4.	Corn six parts, tankage one part	164	353	59	..	$4.71	2
5.	Durum wheat six parts, tankage one part	161	360	60	..	$6.60	6
6.	Durum wheat three parts, corn three parts, tankage one part.	173	334	56	..	$5.30	5

* Note—Prices of feed figured as follows:
Corn and barley at one cent per pound.
Wheat at one and one-half cent per pound.
Tankage at $40.00 per ton, (two cents per lb.).
Alfalfa at $5.00 per ton.

DURUM WHEAT, CORN, AND SELECTED TANKAGE.

Lots 5 and 6 were fed rations containing these grains. Lot 5, which received six pounds of durum wheat to every pound of tankage, made a very good gain in weight, and required only about an average amount of feed to produce 100 pounds gain, so that if the prices of these feeds were not considered the ration would be pronounced a good one. Both feeds are expensive, however, and consequently the cost of gain is too high.

Lot 6, fed durum wheat, three pounds, corn, three pounds, and tankage, one pound, made the best gains of any lot, gaining an average of eleven and one-half pounds per head each week. These required less feed for gain than any of the other lots. If durum wheat can be obtained at the price of corn, this ration will prove very economical.

BARLEY, CORN, ALFALFA HAY.

This ration proved very satisfactory the previous winter, but did not show quite so great economy in the present experiment. The amount of feed required for gain was somewhat greater than the previous winter, and the gains made were less than those made by the other lots in this experiment. This might be accounted for by a difference in the quality of the hays. At any rate, in this instance, the barley, corn, hay ration proved more costly than barley and tankage; corn and tankage; or barley, corn and tankage; although at a cost of $5.10 for each hundred pounds gain, it is still a very good ration.

BARLEY, CORN AND SELECTED TANKAGE.

This ration, with the feeds in the proportion of 3 : 3 : 1, gave the best results of any tried in this experiment. The gain made was eleven and two-fifths pounds per head each week. The amount of feed required for gain was only 336 pounds of grain and 56 pounds of tankage, and the cost was $4.50 for each hundred pounds gain. This cost was practically the same as that for the corn, barley, and alfalfa lot and for the barley and shorts lot of the previous year.

CORN AND TANKAGE, AND BARLEY AND TANKAGE.

The corn and tankage ration was not quite as economical as the barley, corn, and tankage; but was slightly better than the barley and tankage, the cost of 100 pounds gain for the three lots being $4.71, $4.50 and $4.89. All three of these rations were satisfactory and economical.

It will be seen from the following table that the tankage and the wheat rations all supplied a large proportion of protein, while the alfalfa ration apparently did not. It is probable, however, that the alfalfa rations actually furnished a larger percentage of protein than the tables show, because the pigs eat only the leaves and finer

stems of the hay, while the entire amount of hay is necessarily charged up to them.

TABLE II. (See Table VI in Appendix)

DIGESTIBLE NUTRIENTS REQUIRED FOR 100 LBS. GAIN, ALL PENS

PEN NO.	Total Gain in 15 Weeks lbs.	DIGESTIBLE NUTRIENTS, POUNDS			Nutritive Ratio
		Protein	Carbo-Hydrates	Ether Extracts	
1.	931	45.86	355.86	15.13	8.1
2.	1368	51.32	231.97	17.33	5.33
3.	1260	55.79	255.89	14.05	5.19
4.	1309	53.55	238.50	22.63	5.47
5.	1286	62.75	251.79	13.77	4.54
6.	1383	54.52	229.93	17.14	4.97

CONCLUSIONS.

Sugar Beets.—For light weight fattening pigs, weighing from 60 to 160 pounds, sugar beets are not an economical fattening feed in connection with grain, when they constitute approximately one-half of the ration by weight. Our experience indicates that when such pigs are fed beets at pleasure, they will eat the beets and grain in about equal proportions by weight.

Alfalfa Hay.—Where a good quality of leafy alfalfa hay may be had at reasonable cost, and other protein feeds are difficult to obtain or are high in price, the alfalfa hay may be used to supplement grain feed for fattening pigs. It should not be fed with the grain, but should be put in specially constructed racks where the pigs may go to it at pleasure. Mixed grains, with alfalfa hay will give better results than a single grain with hay as a rule.

Barley and Shorts.—Two home grown feeds that can be secured almost anywhere in the State. They make a first class ration when fed together. The millers of Colorado do not ordinarily separate shorts from bran, but will usually do so upon request, at a price about ten cents per hundred in advance of the price of bran.

Barley and Wheat.—Another home grown combination that gives good results. Where a sufficient yield of durum wheat can be secured on the dry lands of the State, this ration will prove particularly well suited to those regions.

Barley and Peas.—Field peas, threshed, are more expensive than a number of other high protein feeds, so that it is well to confine pea feeding to the hogging off of field peas.

Selected Tankage.—This is a very high protein feed containing over 40% of protein; so that only a small quantity of it is necessary with grain. It proved satisfactory when fed either in the proportion of one-eleventh of the ration, or one-seventh of the

ration. With grain at one cent per pound and tankage at two cents per pound, the grain and tankage ration, with the grain forming five-sixths to nine-tenths of the ration, will cost from about $4.50 to $5.25 for each 100 pounds gain upon fattening pigs under two hundred pounds live weight.

What Selected Tankage Is.—The following description of the manufacture of Digester Tankage by Swift & Co., of Chicago, under date of Oct. 3, 1908, gives a good general idea of the methods used in the manufacture of selected tankage for feeding purposes. Such tankage does not contain any part of the animal carcasses condemned because of disease, and if any disease germs should find their way in with foreign matter they would be destroyed by the cooking process with live steam under pressure.

"Digester Tankage is made from small scraps of meat trimmed from residues left in tanks after edible lard and tallow have been extracted from the carcass trimmings, and residues incident to the production of meats for human food purposes. These materials are taken only from animals which have been U. S. Government inspected and passed. This meat is a finished product and is a safe feed, absolutely free from diseased germs.

"In the process of manufacture, the materials mentioned are placed in large tanks which are then sealed and the mass subjected to live steam, usually under a pressure of 40 pounds. The cooking process is timed for four to six hours, depending upon the character of materials handled. When the cooking is completed the steam is turned off and tanks allowed to settle. When the liquid fat is found in a layer at the top it is removed. The residues consist of a watery solution, and at the bottom of the tanks a mixture of small pieces of meat and bone. The liquid is drained off to be dried separately and the solid meat—"The Tankage"—allowed to drain; it is then dried in large steam-heated rotary ovens in which a high temperature is maintained. The dried tankage is ground and put through a mill and screened to the desired fineness. It is then packed in 100-pound sacks ready for shipment.

"Digester Tankage has a very uniform composition, guaranteed 60% Protein, 6% Phosphates, and 8% Fat."

Armour Packing Company, of Kansas City, make the following statements under date of October and November, 1908:

"Our guarantee to the State of Kansas regarding meat meal is as follows:

> 'Made from regular run of good conditioned cattle and sheep offal from which oils and greases have been extracted. Sold under guarantee to contain a minimum of sixty per cent (60%) Protein, but will run as high as sixty-five per cent (65%) in certain lots.'

"This means too only the best of the offal, for what is commonly known as "peck" never goes into such tanks, being kept apart, and the residue of "peck" tanks goes to fertilizer only.

"Recent analyses of our Meat Meal show that in addition to 60% proteids, it contains about 13% fat, and 14.5% ash.

"There is not properly any crude fibre in this, and what foreign matter may get in will not exceed half of one per cent."

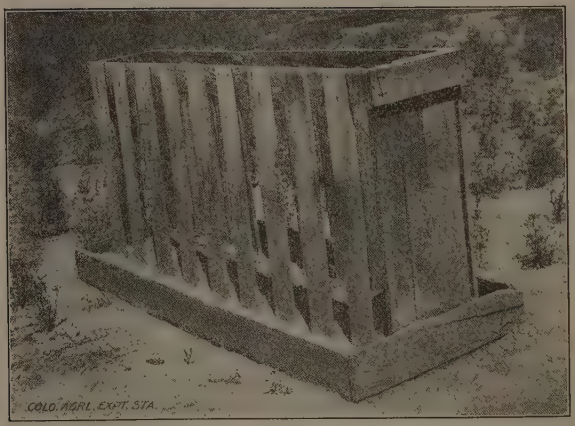
The Colorado Packing and Provision Company of Denver, who furnished the selected tankage used in these experiments, have the following to say concerning their product, under date of Oct. 19, 1908:

"We will state as near as possible the analysis of our Selected Beef Tankage for stock food:

Water	10%
Protein	55%
Crude Fibre	5%
Free Extract of Nitrogen	7%
Fat	8%
Phosphate of Lime	15%

"This will vary some, as our material is not always uniform, but we will make it as near the above as possible."

SHED AND FEED YARDS USED FOR EXPERIMENTS



RACK FOR FEEDING ALFALFA HAY TO HOGS

APPENDIX

The Tables in the Appendix give the original data of the experiments. The Tables in the body of the bulletin were compiled from these.

WEEKLY DATA, PEN 1. 1906-07
(Ten head in each pen.)

Barley; alfalfa hay at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Alfalfa Hay
Beginning	838	...	...	...	...
1st week	811	—2.7	—2.7	303	144
2nd week	937	126	12.6	390	90
3rd week	1025	88	8.8	406	54
4th week	1102	77	7.7	395	54
5th week	1156	54	5.4	395	76
6th week	1243	87	8.7	445	20
7th week	1390	147	14.7	473	60
8th week	1479	89	8.9	397	60
9th week	1530	51	5.1	430	60
10th week	1522*	102	10.2	420	60
11th week	1573	51	5.1	450	60
12th week	1694	121	12.1	485	20
13th week	1794	100	10.0	445	40
		1066§	106.6	5434	798

* piggy sow, weight 205 lbs., put out; 95lb barrow put in.
§ 956 lbs. plus 110 lbs. lost by exchanging pigs.

WEEKLY DATA, PEN 2. 1906-07
(Ten head in each pen.)

Corn; alfalfa hay at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Corn	Alfalfa Hay
Beginning	669	...	...	...	...
1st week	823	154	15.4	303	144
2nd week	896	73	7.3	384	90
3rd week	995	99	9.9	406	54
4th week	1066	71	7.1	420	54
5th week	1125	59	5.9	420	76
6th week	1202	77	7.7	450	60
7th week	1310	108	10.8	483	60
8th week	1393	83	8.3	467	60
9th week	1477	84	8.4	470	60
10th week	1548	71	7.1	440	60
11th week	1622	74	7.4	530	80
12th week	1737	115	11.5	565	40
13th week	1814	77	7.7	475	40
		1145	114.5	5813	878

WEEKLY DATA, PEN 3. 1906-07

(Ten head in each pen.)

Barley and corn, equal parts, and alfalfa hay at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.		
				Barley	Corn	Alfalfa Hay
Beginning	688	...	...	...	...	...
1st week	796	108	10.8	152	152	144
2nd week	894	98	9.8	176	176	90
3rd week	992	98	9.8	190	190	54
4th week	1084	92	9.2	189	210	54
5th week	1145	61	6.1	193	210	76
6th week	1230	85	8.5	248	210	60
7th week	1368	138	13.8	230	230	60
8th week	1474	106	10.6	210	210	60
9th week	1549	75	7.5	240	240	60
10th week	1661	112	11.2	220	240	60
11th week	1737	76	7.6	290	280	80
12th week	1868	131	13.1	260	250	40
13th week	1991	123	12.3	240	250	40
		1303	130.3	2838	2848	878

WEEKLY DATA, PEN 4. 1906-07

(Ten head in each pen.)

Barley and wheat, equal parts.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Wheat
Beginning	671	...	...	...	...
1st week	788	117	11.7	152	152
2nd week	879	91	9.1	187	187
3rd week	970	91	9.1	192	192
4th week	1034	64	6.4	167	208
5th week	1103	69	6.9	193	210
6th week	1193	90	9.0	241	210
7th week	1313	120	12.0	235	210
8th week	1395	82	8.2	191	210
9th week	1460	65	6.5	239	230
10th week	1544	84	8.4	220	210
11th week	1621	77	7.7	250	260
12th week	1729	108	10.8	240	250
13th week	1824	95	9.5	195	250
		1153	115.3	2702	2779

WEEKLY DATA, PEN 5. 1906-07

(Ten head in each pen.)

Barley and peas, equal parts.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Peas
Beginning	687	...	...	...	...
1st week	812	125	12.5	140	140
2nd week	879	67	6.7	161	161
3rd week	988	109	10.9	180	180
4th week	1062	74	7.4	166	210
5th week	1121	59	5.9	167	210
6th week	1103*	59	5.9	235	210
7th week	1241	138	13.8	249	210
8th week	1333	92	9.2	210	210
9th week	1402	69	6.9	247	230
10th week	1509	107	10.7	246	240
11th week	1588	79	7.9	240	240
12th week	1686	98	9.8	250	250
13th week	1722	36	3.6	182	182
		1112§	111.2	2673	2673

* 147 lb. pig taken out; 70 lb. pig put in.

§ 1035 lbs. plus 77 lbs. lost in exchanging pigs.

WEEKLY DATA, PEN 6. 1906-07

(Ten head in each pen.)

Barley and shorts, equal parts.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Shorts
Beginning	665	...	...	...	...
1st week	772	107	10.7	152	152
2nd week	873	101	10.1	176	176
3rd week	974	101	10.1	180	180
4th week	1049	75	7.5	210	210
5th week	1138	89	8.9	202	210
6th week	1195	57	5.7	203	210
7th week	1322	127	12.7	194	210
8th week	1396	74	7.4	190	210
9th week	1464	68	6.8	249	210
10th week	1582	118	11.8	222	210
11th week	1619	37	3.7	240	250
12th week	1765	146	14.6	220	210
13th week	1833	68	6.8	230	250
		1168	116.8	2668	2688

WEEKLY DATA, PEN 7. 1906-07

(Ten head in each pen.)

Barley and tankage, nine to one.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Tankage
Beginning	688	...	...	...	...
1st week	786	98	9.8	252	28
2nd week	898	112	11.2	324	36
3rd week	1035	137	13.7	400	44.4
4th week	1148	113	11.3	389	47.6
5th week	1188	40	4.0	393	50
6th week	1319	131	13.1	426	50
7th week	1430	111	11.1	511	50
8th week	1533	103	10.3	398	50
9th week	1610	77	7.7	433	50
10th week	1721	111	11.1	400	45
11th week	1768	47	4.7	450	45
12th week	1925	157	15.7	495	50
13th week	1987	62	6.2	395	50
		1299	129.9	5266	596

WEEKLY DATA, PEN 8. 1906-07

(Ten head in each pen.)

Corn and tankage, nine to one.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Corn	Tankage
Beginning	686	...	...	...	...
1st week	778	92	9.2	252	28
2nd week	889	111	11.1	324	36
3rd week	1005	116	11.6	400	44.4
4th week	1126	121	12.1	423	47.6
5th week	1190	64	6.4	392	50
6th week	1210*	117	11.7	432	50
7th week	1351	141	14.1	453	50
8th week	1444	93	9.3	362	50
9th week	1516	72	7.2	457	50
10th week	1652	136	13.6	435	45
11th week	1707	55	5.5	495	45
12th week	1869	162	16.2	540	50
13th week	2006	137	13.7	510	50
		1417§	141.7	5475	596

* 162 lb. pig taken out and 65 lb. pig put in.

§ 1320 lbs. plus 97 lbs. lost by exchanging pigs.

WEEKLY DATA, PEN 9. 1906-07

(Ten head in each pen.)

Beets and barley, at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Beets
Beginning	686	...	...	...	...
1st week	737	51	5.1	160	320
2nd week	838	98	9.8	219	438
3rd week	921	86	8.6	320	640
4th week	1006	85	8.5	284	700
5th week	1056	50	5.0	336	350
6th week	1125	69	6.9	408	300
7th week	1205	80	8.0	359	300
8th week	1276	71	7.1	343	300
9th week	1337	61	6.1	373	300
10th week	1403	66	6.6	350	250
11th week	1440	37	3.7	460	250
12th week	1537	97	9.7	460	150
13th week	1626	89	8.9	390	200
		940	94.0	4462	4498

WEEKLY DATA, PEN 10. 1906-07

(Ten head in each pen.)

Beets and corn, at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Corn	Beets
Beginning	680	...	...	...	...
1st week	776	96	9.6	160	320
2nd week	848	72	7.2	219	438
3rd week	921	73	7.3	320	640
4th week	981	60	6.0	350	700
5th week	1044	63	6.3	350	150
6th week	1090	46	4.6	400	300
7th week	1158	68	6.8	425	300
8th week	1221	63	6.3	349	300
9th week	1297	76	7.6	426	300
10th week	1351	54	5.4	385	250
11th week	1390	39	3.9	440	250
12th week	1478	88	8.8	440	150
13th week	1543	65	6.5	435	200
		863	86.3	4699	4298

TABLE C.

TOTAL FEED, WEIGHTS AND GAINS, ALL PENS, 1906-07

(13 weeks. 10 pigs in each pen.)

PEN NO.	INITIAL WEIGHT	CLOSING WEIGHT	GAIN	TOTAL FEED CONSUMED								NUTRITIVE RATIO
				Corn	Barley	Shorts	Peas	Wheat	Beets	Tankage	Alfalfa Hay	
I.	838	1794	1066*	----	5434	----	----	----	----	----	798	7.80
II.	669	1814	1145	5813	----	----	----	----	----	----	878	7.90
III.	688	1991	1303	2848	2838	----	----	----	----	----	878	7.81
IV.	671	1824	1153	----	2702	----	----	2779	----	----	----	8.05
V.	687	1722	1112§	----	2673	----	2673	----	----	----	----	4.27
VI.	665	1833	1168	----	2668	2688	----	----	----	----	----	6.55
VII.	688	1987	1299	----	5266	----	----	----	----	596	----	5.58
VIII.	686	2006	1417‡	5475	----	----	----	----	----	596	----	6.40
IX.	686	1626	940	----	4462	----	----	----	4498	----	----	11.23
X.	680	1543	863	4699	----	----	----	----	4298	----	----	11.54

* 110 lbs. credit. See weekly data.
§ 77 lbs. credit. See weekly data.
‡ 97 lbs. credit. See weekly data.

TABLE D.

ANALYSES OF FEEDS, 1906-07

	Dry Matter	Protein	Crude Fibre	Nitrogen Free Extract	Ether Extract
3. Barley	93.465	11.372	7.795	70.713	1.95
3. Peas	93.325	21.743	3.580	63.822	1.345
1. Alfalfa Hay	93.39	16.11	37.24	28.90	1.18
2. Sugar Beets	98.338	8.578	8.515	75.398	0.378
3. Denver Tankage	97.265	46.744	2.730	7.308	13.078
4. Swift's Tankage	93.75	42.15	6.95	15.50	16.30
4. Armour's Tankage	90.95	39.10	10.90	8.60	11.70

1. Analysis obtained from Colorado Bulletin No. 35, page 31.
2. Analysis obtained from Colorado Bulletin No. 46, page 37.
3. Analysis by Douglas of C. A. C.
4. Analysis from Iowa Bulletin No. 65, (1902). Given for comparison.

TABLE E.

* PERCENTAGE DIGESTIBLE NUTRIENTS IN FEEDS, 1906-07

	DIGESTIBLE NUTRIENTS			
	Dry Matter	Protein	Carbo-Hydrates	Ether Extract
Corn	89.1	7.9	66.7	4.3
Wheat	89.5	10.2	69.2	1.7
Barley	80.4	7.96	68.9	1.7
Peas	81.2	18.0	36.1	0.74
Shorts	88.2	12.2	50.0	3.8
‡Denver Tankage	90.4	43.5	5.0	12.8
Alfalfa Hay	56.03	11.92	35.09	0.46
§Sugar Beets	87.5	5.3	75.9	0.19

* Co-efficients taken from "Feeds & Feeding," by Henry.

‡ Percentages (Meat Scrap), "Feeds & Feeding," by Henry. Carbo-Hydrates estimated at 50%.

§ Percentage of crude fibre and ether extract digestible estimated at 50%.

TABLE F. (Compiled from preceding tables.)

FEED AND DIGESTIBLE NUTRIENTS CONSUMED BY ALL PENS. 13 WEEKS, 1906-07

PEN NO.	TOTAL FEED				TOTAL DIGESTIBLE NUTRIENTS			
	Total Grain	Hay	Beets	Tankage	Protein	Carbo-Hydrates	Ether Extract	Nutritive Ratio
I	5434	798	....	...	528	4024	96.0	7.8
II	5813	878	....	...	564	4185	254.0	7.9
III	5686	878	....	...	556	4162	174.9	7.81
IV	5481	...	....	...	498	3785	93.2	8.05
V	5346	...	....	...	694	2807	65.2	4.27
VI	5376	...	....	...	542	3196	147.8	6.55
VII	5266	...	....	596	678	3658	165.8	5.98
VIII	5475	...	....	596	692	3682	311.7	6.40
IX	4462	...	4498	...	593	6488	84.4	11.28
X	4699	...	4298	...	598	6396	210.2	11.54

WEEKLY DATA, PEN 1. 1907-08

(Eight head in pen.)

Ration: Barley 3 parts, corn 3 parts, alfalfa hay at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per head Lbs.	FEED LBS.		
				Barley	Corn	Alfalfa Hay
Beginning	484	..	....	..	..	..
1st week	543	59	7.38	83	83	28
2nd week	610	67	8.38	105	105	34
3rd week	666	56	7.00	117	117	39
4th week	745	79	9.88	132	132	44
5th week	793	48	6.00	143	143	47
6th week	850	57	7.13	143	143	40
7th week	921	71	8.88	150	150	42
8th week	972	51	6.38	150	150	36
9th week	1034	62	7.75	162	162	40
10th week	1101	67	8.38	162	162	30
11th week	1152	51	6.38	172	172	34
12th week	1200	48	6.00	195	195	30
13th week	1280	80	10.00	195	195	28
14th week	1368	88	11.00	200	200	25
15th week	1415	47	5.88	200	200	22
		931	116.00	2309	2309	519

WEEKLY DATA, PEN 2. 1907-08

(Eight head in pen.)

Ration: Barley 3 parts, corn 3 parts, tankage 1 part.

	WEIGHT LBS.	GAIN LBS.	AVERAGE GAIN PER HEAD LBS.	FEED LBS.		
				Barley	Corn	Tankage
Beginning	487	...	....	...	...	..
1st week	520	33	4.13	83	83	28
2nd week	634	114	14.25	105	105	34
3rd week	700	66	8.25	117	117	39
4th week	775	75	9.38	132	132	47
5th week	850	75	9.38	143	143	47
6th week	962	112	14.00	144	144	48
7th week	1081	119	14.88	150	150	50
8th week	1158	77	9.63	150	150	50
9th week	1262	104	13.00	162	162	54
10th week	1376	114	14.25	162	162	54
11th week	1475	99	12.38	172	172	57
12th week	1569	94	11.75	195	195	65
13th week	1660	91	11.38	195	195	65
14th week	1752	92	11.50	198	198	66
15th week	1855	103	12.88	204	204	68
		1368	171.00	2312	2312	769

WEEKLY DATA, PEN 3. 1907-08

(Eight head in pen.)

Ration: Barley 6 parts, tankage 1 part.

	WEIGHT LBS.	GAIN LBS.	AVG. GAIN PER HEAD LBS.	FEED LBS.	
				Barley	Tankage
Beginning	485	...	....	...	..
1st week	531	46	5.75	166	28
2nd week	636	105	13.13	210	34
3rd week	696	60	7.50	234	39
4th week	775	79	9.88	264	44
5th week	852	77	9.63	286	47
6th week	920	68	8.50	288	48
7th week	1027	107	13.38	300	50
8th week	1100	73	9.13	300	50
9th week	1222	122	15.25	324	54
10th week	1319	97	12.13	324	54
11th week	1400	81	10.13	344	57
12th week	1470	70	8.75	390	65
13th week	1578	108	13.50	390	65
14th week	1672	94	11.75	396	66
15th week	1745	73	9.13	408	68
		1260	158.00	4624	769

WEEKLY DATA, PEN 4. 1907-08

(Eight head in pen.)

Ration: Corn 6 parts, tankage 1 part.

	Weight Lbs.	Gain Lbs.	Average Gain Per Head Lbs.	FEED LBS.	
				Corn	Tankage
Beginning	486	...	....	...	..
1st week	510	24	3.00	166	28
2nd week	600	90	11.25	210	34
3rd week	679	79	9.88	234	39
4th week	736	57	7.13	264	44
5th week	826	90	11.25	286	47
6th week	922	96	12.00	288	48
7th week	1026	104	13.00	300	50
8th week	1112	86	10.75	300	50
9th week	1219	107	13.38	324	54
10th week	1332	113	14.13	324	54
11th week	1425	93	11.63	344	57
12th week	1510	85	10.63	390	65
13th week	1617	107	13.38	390	65
14th week	1704	87	10.88	396	66
15th week	1795	91	11.38	408	68
		1309	164.00	4624	769

WEEKLY DATA, PEN 5. 1907-08

(Eight head in pen.)

Ration: Durum wheat 6 parts, tankage 1 part.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Durum Wheat	Tankage
Beginning	484				
1st week	515	31	3.88	166	28
2nd week	598	83	10.38	210	34
3rd week	692	94	11.75	234	39
4th week	760	68	8.50	264	44
5th week	856	96	12.00	286	47
6th week	892	36	4.50	288	48
7th week	1013	121	15.13	300	50
8th week	1123	110	13.75	300	50
9th week	1218	95	11.88	324	54
10th week	1315	97	12.13	324	54
11th week	1433	118	14.75	344	57
12th week	1492	59	7.38	390	65
13th week	1602	110	13.75	390	65
14th week	1673	71	8.88	396	66
15th week	1770	97	12.13	408	68
		1286	161.00	4624	769

WEEKLY DATA, PEN 6. 1907-08

(Eight head in pen.)

Ration: Durum wheat 3 parts, corn 3 parts, tankage 1 part.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.		
				Durum Wheat	Corn	Tankage
Beginning	487					
1st week	533	46	5.75	83	83	28
2nd week	606	73	9.13	105	105	34
3rd week	692	86	10.75	117	117	39
4th week	767	75	9.38	132	132	44
5th week	857	90	11.25	143	143	47
6th week	950	93	11.63	144	144	48
7th week	1066	116	14.50	150	150	50
8th week	1158	92	11.50	150	150	50
9th week	1262	104	13.00	162	162	54
10th week	1370	108	13.50	162	162	54
11th week	1469	99	12.38	172	172	57
12th week	1552	83	10.38	195	195	65
13th week	1644	92	11.50	195	195	65
14th week	1768	124	15.50	198	198	66
15th week	1870	102	12.75	204	204	68
		1383	173.00	2312	2312	769

TABLE III.

TOTAL FEED, WEIGHTS AND GAINS, ALL PENS 1907-08

(15 weeks, 8 pigs in each lot.)

PEN NO.	Weight at Beginning	Weight at Close	Gain in Weight	TOTAL FEED CONSUMED					Nutritive Ratio
				Barley	Corn	Durum Wheat	Tankage	Alfalfa Hay	
I.	484	1415	931	2309	2309	....	...	519	8.10
II.	487	1855	1368	2312	2312	....	769	...	5.33
III.	485	1745	1260	4624	....	....	769	...	5.19
IV.	486	1795	1309	....	4624	....	769	...	5.47
V.	484	1770	1286	....	....	4624	769	...	4.54
VI.	487	1870	1383	....	2312	2312	769	...	4.97

TABLE IV.

ANALYSES OF FEEDS, 1907-1908

	Dry Matter	Protein	Crude Fibre	Nitro-Free Extract	Ether Extract
Barley	93.465	11.372	7.795	70.713	1.95
Durum Wheat	90.189	10.394	2.746	71.185	2.217
Selected Tankage.....	97.265	46.744	2.730	7.308	13.078
Alfalfa Hay.....	93.39	16.11	37.24	28.90	1.18

TABLE V.

PERCENTAGE DIGESTIBLE NUTRIENTS IN FEEDS, 1907-1908 *

	Dry Matter	Protein	Carbo-Hydrates	Ether Extract
Barley	80.4	7.96	68.9	1.7
Corn §	89.1	7.9	66.7	4.3
Durum Wheat	89.5	10.2	69.2	1.7
Selected Tankage †	90.4	43.5	5.0	12.8
Alfalfa Hay	56.03	11.92	35.09	0.46

* Coefficients obtained from Henry's "Feeds and Feeding."
§ Coefficients used from common wheat.
‡ Percentages used from meat scraps.

TABLE VI. (Compiled from preceding tables.)

FEED AND DIGESTIBLE NUTRIENTS CONSUMED, 1907-1908

(All pens, 15 weeks.)

PEN NO.	TOTAL FEED			TOTAL DIGESTIBLE NUTRIENTS			
	Total Grain	Hay	Tankage	Protein	Carbo-Hydrates	Ether Extract	Nutritive Ratio
I.	4618	519	...	427	3313	140.90	8.10
II.	4624	...	769	702	3173	237.14	5.33
III.	4624	...	769	703	3224	177.03	5.19
IV.	4624	...	769	701	3122	297.25	5.47
V.	4624	...	769	807	3238	177.04	4.54
VI.	4624	...	769	754	3180	237.04	4.97

Bulletin 166 August, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

Information Concerning the Colorado Carriage Horse Breeding Station

BY

JOHN O. WILLIAMS

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1910

The Agricultural Experiment Station

FORT COLLINS, COLORADO

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Information Concerning the Colorado Carriage Horse Breeding Station

By JOHN O. WILLIAMS

This circular is not intended as a publication of any results attained in the carriage horse breeding experiment, but is intended as a *circular of information* so that interested persons may acquaint themselves with the object of the experiment conducted at the Colorado Breeding Station and the conditions by which they may avail themselves of the services of the various stallions in use at the station.

HISTORY AND OBJECT OF EXPERIMENT.

On July 1. 1904 an appropriation of $25,000 by Congress became available to the U. S. Bureau of Animal Industry for experiments in animal breeding and feeding in cooperation with the State Experiment Stations. Under this Act, carriage horse breeding was inaugurated in cooperation with the Colorado Experiment Station.

The first purchase of foundation stock was made in December, 1904 from George D. Rainsford, Diamond, Wyoming, and comprised six mares of excellent breeding and good carriage conformation. The next purchase was made in February, 1905 and included the standard-bred stallion "Carmon" 32917 (formerly shown as Glorious Thundercloud) and twelve trotting-bred mares of superior merit as show animals. These mares were bred in the various middle-western states and in Kentucky. The next purchase was made in June, 1906 and included the two saddle-bred mares Beatrice 2079 (S) and Mambrina 2400 (S). The last purchase was made in March, 1908 and comprised four mares from various breeders in Kentucky. These mares were Golden Picture 2788 (S); Bethel Princess 4796 (S); Barthenia McCord 4223 (S), and Elvira Lindsey 3083 (S).

The above named animals constitute the foundation animals of the experiment. The progeny of the foundation mares are carefully selected, and those adhering closely to the desired type are retained for breeding purposes. New blood will also be introduced from time to time through mating the offspring of the foundation mares to stallions other than those in use at the station, as well as through the purchase of additional animals.

The object of the work is to study the possibilities of evolving an American carriage horse from the American trotter, Morgan, and American saddle horse. The trotter is being used as the basis of the work and the two other native-blood lines are being used to supply the desired qualities they are known to possess. Through judicious blending of these blood lines, the ultimate American

carriage horse will be realized. This does not mean that animals which will fill the requirements are not already available as many specimens of "native" breeding have demonstrated their high carriage qualities by defeating the best imported animals in competition in the show ring. The encouragement for the retention of these outstanding individuals for breeding purposes is one of the admirable objects of the work by the department.

The qualities desired in a high class carriage horse are substance, quality, stamina or endurance, high-balanced action, good temperament and speed. The latter qualification is very desirable in most cases, but not in itself essential in the production of either a marketable or high-class carriage individual.

In order to present the desired qualifications of a carriage horse to the breeders, and also to encourage the production of a uniform type of carriage horse, the U. S. Department of Agriculture in cooperation with the American Association of Trotting Horse Breeders, has formulated a classification for American carriage horses which has been adopted by the various State Fairs throughout the United States. *

The classification is as follows:

TYPE.

The type desired for the American carriage horse is as follows: Not under 15 hands for mature horses; smooth, compact, and symmetrical conformation; neck of good length, inclined naturally to arch; sloping shoulders; well-set legs of medium length; sloping pasterns and good feet; short, strong back; well sprung ribs well ribbed up to coupling; smooth loins; full flanks; straight croup, with well-set tail; full round quarters.

CONDITIONS GOVERNING ENTRIES.

Classes open only to horses of American blood.

Stallions in classes 1 to 5, inclusive, must be registered either in the American Trotting Register as standard, in the American Morgan Register, or in the American Saddle Horse Register, and certificate of such registry must be shown in the ring if required.

Entries in all classes for mares must be registered either in the American Trotting Register as standard or non-standard, in the American Morgan Register, or in the American Saddle Horse Register, and certificate of such registry must be shown in the ring if required.

Entries as get of sire in class 5 and produce of mare in class 10, and entries in class 11 must be sired by a stallion registered as above, out of mares registered as above.

No mare having any draft cross will be eligible.

*From Twenty-Fourth Annual Report, B. A. I., U. S. Department of Agriculture.

Any exhibitor falsifying the breeding of entries will be barred.

Entries in all classes must be practically sound.

JUDGING.

Entries in all classes to be judged on conformation, style, action, and manners as a suitable type of carriage horse. Special attention will be given to trueness of action. Good knee and hock action are essential. Entries in all classes should trot and walk straight and true, and judges will especially avoid horses showing a tendency to pace, mix gaits, paddle in front or sprawl behind.

The following percentages will govern judges in classes 1, 2,

STUD NO. 1. CARMON 32917, AT 15 YEARS OF AGE.
Standard bred carriage stallion, shown as "Glorious Thundercloud." At the head of the Government stud at the Colorado Experiment Station.

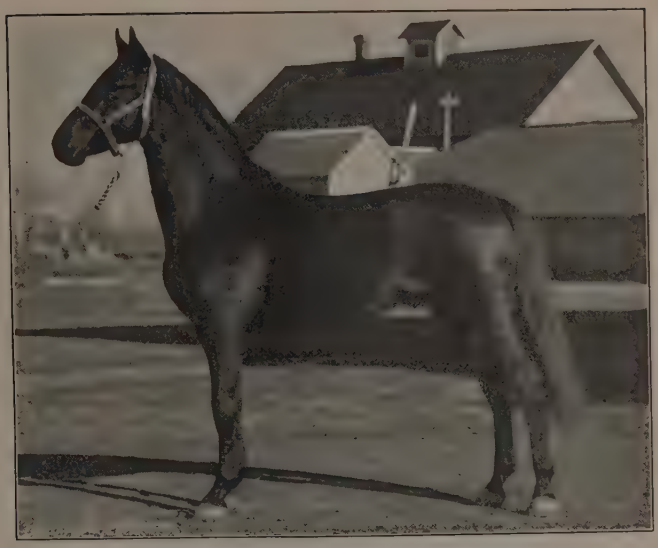
3, 4, 6, 7, 8, 9: General conformation and all-round suitability as a carriage type, 60 per cent; style, action, and manners, 40 per cent.

The following percentages will govern in class 5: General conformation and all-round suitability of sire as a carriage type, 30 per cent; style, action, and manners of sire, 20 per cent; general conformation and all-round suitability of get as a carriage type, taken as a whole, 30 per cent; style, action, manners, and uniformity of type in get, 20 per cent.

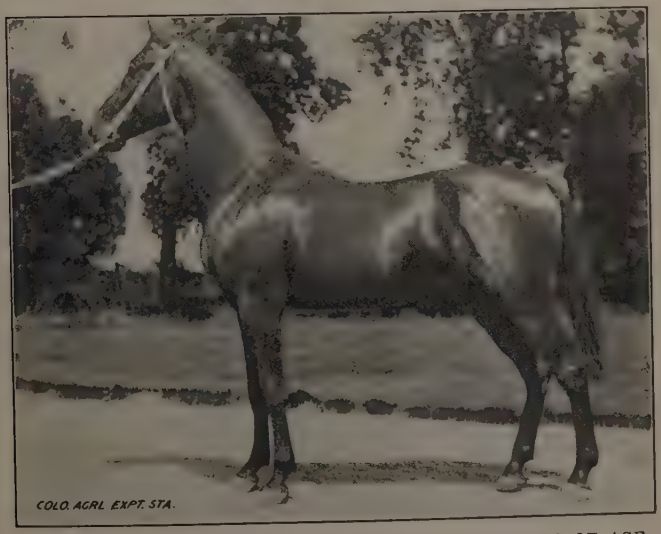
The following percentages will govern in class 10: General conformation of dam as a brood mare of the carriage type, 50 per

STUD NO. 37, ALBION, AT 4 YEARS OF AGE.

STUD NO. 39, ALVA, AT 4 YEARS OF AGE.



STUD NO. 40, BALFOUR, AT 3 YEARS OF AGE.



STUD NO. 46, CHESTER BOURBON 3577 (S), AT 2 YEARS OF AGE.

cent; general conformation, style, action, and manners of the foal, 50 per cent.

The following percentages will govern in class 11: General conformation of entry as a carriage type, 70 per cent; style, action, and manners, 30 per cent.

MANNER OF SHOWING.

Entries in classes 1, 2, 6, and 7 to be shown in harness, hitched to any suitable vehicle. Entries in all other classes to be shown in hand to bridle or halter. Excessive weight in shoeing in any class is forbidden.

CLASSES.

Class 1. Stallion 4 years old or over.
Class 2. Stallion 3 years old and under 4.
Class 3. Stallion 2 years old and under 3.
Class 4. Stallion 1 year old and under 2.
Class 5. Stallion with three of his get of either sex; get need not be owned by exhibitor.
Class 6. Mare 4 years old or over.
Class 7. Mare 3 years old and under 4.
Class 8. Mare 2 years old and under 3.
Class 9. Mare 1 year old and under 2.
Class 10. Mare and foal of either sex.
Class 11. Foal under 1 year old, either sex.

The above classification, if carefully studied, will give the breeder a definite idea of what is desirable in an American carriage horse. The classification is not intended to antagonize or conflict in any way with the classifications offered for individuals possessing the blood lines mentioned therein. The type desired is distinct from either those required in the American Trotter, American Saddle or Morgan classification.

SALE OF SURPLUS ANIMALS.

The animals used in connection with the breeding operations at the station, along with their offspring, are inspected annually by a Board of Survey consisting of Mr. Geo. M. Rommel, Chief of Animal Husbandry Division, U. S. Department of Agriculture; Professor C. F. Curtiss, Director of Iowa Experiment Station, and the officer in charge of the breeding establishment, with a view of determining the producing qualities of the various animals in the stud and the progress made during the preceding year. In the past the inspection has resulted in the elimination of some of the original herd of mares and many of the offspring produced at the station and placing them on sale to the public at auction. The animals eliminated from the stud in this manner are sold without reserve and also without obligation on the part of the station to the buyer after the animal is sold.

STALLIONS IN SERVICE.

The stallions described herein will be allowed to stand for public service to a limited number of approved mares.

CARMON—32917, Stud No. 1. *

The stallion Carmon is the foundation sire in service at the breeding station. He is a bright bay, standing 16 hands in height and weighs 1250 pounds. Carmon is a standard bred stallion of carriage type.

PEDIGREE OF CARMON

CARMON ----- No. 32917.

[Breed standard bred; sex, male; color, bay; height, 16 hands; weight, 1,250 pounds; date of birth, 1895. Breeder, Norman J. Colman, St. Louis, Mo. At Stud, Colorado Experiment Station, Fort Collins. Colo.

- Carnagie ---- No. 8405.
  - Robert McGregor No. 647.
    - Major Edsall ------ No. 211.
      - Abdallah. No. 15.
      - By Harris's Hambletonian No. 2.
    - Nancy Whitman
      - American Star No. 14.
      - Nance, by Young Messenger Duroc
  - Annie Nutwood -- (non-standard) Vol. VI. p. 376, A. T. R.
    - Nutwood ----- ---- No. 600.
      - Belmont, No. 64
      - Miss Russell by Pilot. jr., No. 12
    - Annie Watson -----
      - Vermont Boy.
      - ----------
- Monitor MaidVol. XI. p. 646, A. T. R.
  - Monitor ---------- No. 1327.
    - Merchant---------- No. 599.
      - Belmont, No. 64.
      - Lady Mambrino by Mambrino Chief No. 11.
    - Trojana ----------
      - Trojan. No. 312
      - By Hercules
  - Clara C---------- Vol. XI, p. 389, A. T. R.
    - Seth Warner ------ No. 281.
      - Ethan Allen. No. 43.
      - Sontag, by Harris's Hambletonian, No. 2.
    - Grace----------
      - Abdallah, jr. No. 5720.
      - Glencoe Belle, by Old Bull.

* In giving registry numbers the following system is used to indicate the register in which any given number appears: Those in the American Trotting Register are printed open, thus: Carmon 32917. Those in the American Saddle Horse Register are followed by a capital S in parenthesis, thus: Chester Bourbon 3577 (S). Thoroughbred horses are designated thus: (TH).

ALBION—Stud No. 37.

Albion is a bright bay stallion, standing 16:1 hands in height and weighing 1300 pounds. He was sired by Carmon and his dam, Arizona, was sired by Emigrant. His pedigree is as follows:

PEDIGREE OF ALBION

ALBION Stud No. 37	Carmon No. 32917	Carnagie No. 8405	Robert McGregor, No. 647.	Major Edsall No. 211
				Nancy Whitman
			Annie Nutwood (non standard) Vol. VI., p. 376, A. T. R.	Nutwood No. 600
				Annie Watson
		Monitor Maid Vol. XI., p. 646, A. T. R.	Monitor No. 1327.	Merchant No. 599
				Trojana
			Clara C. Vol. XI., p. 389, A. T. R.	Seth Warner No. 281
				Grace
Sex, male, color, bright bay; height, 16.1 hands; weight, 1,300 pounds; date of birth, April 9, 1906; breeder, Colorado Exp. Station, Fort Collins, Colo.	Arizona Stud No. 17	Emigrant	Lord Winbeam	George Peabody by Hamiltonian No. 10

			Lady Spartan	Spartan by Ethan, Allen 43 (Morgan).

		Hoyden	Red Bud (Th)	Tom Bowling, by Lexington.
				Oleander, by Tipperary.
			Cora	Spartan Jr., by Spartan (Morgan)
				Lady Fauna

ALVA—Stud No. 39.

The stallion Alva is a bright bay in color, standing 15:1½ hands in height and weighing 1100 pounds. His pedigree is as follows:

PEDIGREE OF ALVA

ALVA Stud No. 39	Carmon No. 32917	Carnagie No. 8405	Robert McGregor No. 647	Major Edsall No. 211
				Nancy Whitman
			Annie Nutwood (non-standard) Vol. VI., p. 376, A. T. R.	Nutwood No. 600
				Annie Watson
		Monitor Maid Vol. XI. p. 646, A. T. R.	Monitor No. 1327	Merchant No. 559
				Trojana
			Clara C. Vol. XI., p. 389, A. T. R.	Seth Warner No. 281
				Grace
Sex, male; color, bright bay; height, 15.1½ hands; weight, 1,100 pounds; date of birth, March 23, 1906; breeder, Colorado Exp. Station, Fort Collins, Colorado.	Washington Stud No. 2	C. H. Purcell, 2:19¼ No. 25226	Morgan Messenger	----------
				Red Wilkes, 1749, by Geo. Wilkes 519
		----------	Clermont, 2:28¼	

BALFOUR—Stud No. 40.

Balfour is a dark bay stallion, standing about 15 hands in height and weighing 1025 pounds. He is a stallion of exceptional quality and action. His pedigree is as follows:

PEDIGREE OF BALFOUR

BALFOUR Stud No. 40	Carmon No. 32917	Carnagie No. 8405	Robert McGregor No, 647	Major Edsall No. 211
				Nancy Whitman
			Annie Nutwood (non-standard) Vol. VI., p. 376, A. T. R.	Nutwood No. 600
				Annie Watson
Sex, male; color, dark bay; height 15 h'ds: weight, 1,025; pounds: date of birth, April 19, 1907; breeder, Colorado Exp. Station, Fort Collins, Colo.	Dakota, Stud No. 7 (In service at Experiment'l Station)	Monitor Maid Vol. XI., p. 646, A. T. R.	Monitor No. 1327	Merchant No. 599
				Trojana
			Clara C. Vol. XI., p. 389, A. T. R.	Seth Warner No. 281
				Grace

CHESTER BOURBON—3577 (S).

This stallion is a registered American Saddle stallion which will be placed in the stud during the season 1911 to a limited number of approved mares. This horse stands 15:2 hands, and weighs 1000 pounds as a two year old. His description and pedigree follows:

PEDIGREE OF CHESTER BOURBON

CHESTER BOURBON No. 3577 (S)	Bourbon King No. 1788 (S)	Bourbon Chief No. 976 (S)	Harrison Chief No. 1606 (S)	Clark Chief No. 89, A. T. R.
				Lute Boyd
			Belle	Latham's Denmark No. 69
				Dau of Bellfounder
		Annie C No. 3025 (S)	King (Wilson's) No. 2196 (S)	Harrison Chief No. 1606 (S)
				Dau. of Parson's Abdallah
			Kate	Richlieu, he by Indian Chief 1718 (S)
				Kate by Kentucky Chief
Breed, American saddle; sex, male; color, bay; height, 15.2 hands; weight, 1,000 pounds; date of birth, May 5, 1908; breeder. A. G. Jones, North Middletown, Ky.	Barthenia McCord No. 3223 (S)	Chester Dare No. 10 (S)	Black Squirrel No. 58 (S)	Black Eagle No. 74 (S)
				Mollie No. 70 (S)
			Nannie Garett No. 472 (S)	Dave Akin (Th) No. 755 (S)
				Nannie
		Dau.	Peavine No. 85 (S)	Rattler
				Dau. of Wagner Jr. (Th.)
			Dau.	Trojan
				Dau. of Brinker's Drennon, 1600 (S)

The stallions herein named are in service at the station during the season of 1910. Other stallions will mature and be placed in service during each succeeding year, thereby adding to the number now in service.

TERMS OF SERVICE.

Private individuals can avail themselves of the services of the above named stallions under the following conditions:

1. The mares to be bred must be approved by the officer in charge.

2. Service fee must be paid at the time of first service, the amount for each stallion being given below. The groom is instructed not to furnish service unless authorized by the officer in charge.

3. Owners of mares will be allowed return privileges at any time during the breeding season of the same year in which the first service is given. The following fees will prevail until further notice:

Carmon	$25.00
Albion	15.00
Alva	10.00
Balfour	10.00
Chester Bourbon (will be placed in stud, 1911).	

4. The utmost care will be exercised to prevent any accidents while mares are in the custody of the Colorado Experiment Station, but neither the Station nor the Department will be responsible should any occur.

FACILITIES FOR KEEPING OUTSIDE MARES.

The Station is equipped to keep a limited number of mares belonging to private individuals. This arrangement is provided for those who send mares from a distance. Owners of mares living within a convenient distance of the Station cannot be provided with accommodations for their mares.

The following fees will be charged for mares kept at the Station:

For pasturage alone, 50 cents per week for each animal.

For paddock at Station (with hay and pasturage), $1.00 per week for each animal.

For box stall and stable accommodations, $1.50 per week for each animal.

If grain ration is desired, and additional charge of $1.00 per week for each animal will be charged.

Bulletin 167 September, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

A Too Common Farm Scene

LIFE AND CARE OF FARM MACHINERY IN COLORADO

BY

H. M. BAINER *and* H. B. BONEBRIGHT

PUBLISHED BY THE EXPERIMENT STATION
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J. C. SUMMERS, B. S. ..... Assistant Chemist

LIFE AND CARE OF FARM MACHINERY IN COLORADO

By H. M. BAINER and H. B. BONEBRIGHT

The twelfth census report of 1900 places the valuation of the agricultural implements on the farms of Colorado at $4,746,755.00. Knowing of the wonderful development of agriculture in Colorado within the past decade, a conservative estimate would not place the present valuation at less than $10,000,000.00.

In traveling over the state, the ordinary observer is unfavorably impressed with the methods now commonly found in use by our farmers for taking care of their machinery. As a general rule, the prosperity of the farmer may be estimated by the way he cares for his machinery. Poor care indicates shiftlessness, waste, lack of energy and the necessity of buying more machinery in a short time.

Plate 2. The profits from many Colorado farms are found in such "junk heaps" as this.

Good care, on the other hand, indicates prosperity, development, bank deposits, and long lived machinery.

At the present time there is a growing demand for information on the subject of the life and care of farm machinery in Colorado. With the idea of obtaining this information, the Farm Mechanics Department has carefully investigated the machinery conditions on over two hundred representative farms in all parts of the state. This information is summarized in the following remarks:

SELECTION OF MACHINERY.

Type.—The proper care of a farm machine begins in the careful and intelligent selection of the correct type of machine for the work which it is expected to do. This point is too often overlooked

by the man who is strongly prejudiced in favor of some particular make or so-called "line" of implements.

Size.—When the correct type of machine has been selected, its size should be carefully considered. By the use of sufficiently large and strong implements, with large capacity, a great deal of time and labor is saved and the life of the machine is greatly lengthened.

For example, on a fair sized field, a three section harrow will do one-half more work with the same amount of man labor. The teeth, having to travel less distance in harrowing the field, will remain sharp longer, and, consequently, the efficiency of the harrow is increased, while the time required for the work is decreased.

Three section harrows were found in operation on one-third of the enumerated farms of 80 acres and over. Three section harrows were used on but one-half of the enumerated farms of 160 acres and over, the remaining one-half using nothing larger than the two section harrow. In no case was a farmer found who had used a three section harrow and was willing to discard it for one of two sections.

A man of ordinary ability can handle a two bottom gang plow nearly as easily as a sulky, or one bottom plow. By the use of the gang the capacity of man and plow are doubled, while the wear on each plow is only one-half what it would be on the single plow, were it made to cover the same number of acres as the gang. Then too, time is saved in case the shares must be taken to a shop for sharpening, as only one-half as many trips are necessary for the gang as with the single plow, for a field of equal size.

Gang plows, ranging from two to four bottoms, are now being used on less than nine per cent of the farms of 80 acres or more which have been investigated. In communities where suitable gang plows have been tried, the demand for them is increasing.

In some cases, such as gardening, special farming deep work, etc., it is often not advisable to try to cover too much ground at once. Again, some of our special implements are made only in single units, such as the modern two-way plow. This plow has many advantages that will often justify its use in place of the two and four bottom gang plows.

Accessibility to Repairs.—In selecting machinery, it is usually advisable to consider the matter of securing repairs. Repairs or new parts must be secured for nearly every farm implement some time, or perhaps several times, during the life of it. Usually, the repairs are not ordered until the implement will not run any longer without them and then they must be secured in a hurry. For example, the binder, mower, or other important implements or machines must be repaired at once, or the farmer may lose part of his

crop while waiting for repairs. In this case, the question of being able or unable to secure the necessary repairs, may represent the difference between loss and gain on the season's crop. For such implements as are absolutely necessary during certain seasons, the owner should be able to get repairs on not over one day's notice, if not at once. Instances were found where the farmer was compelled to buy a new machine of another make simply because he was unable to ge a repair for his old machine in time to do the necessary work.

Oiling Devices.—Good visible oiling devices should be found on every farm machine. In selecting machinery this point should be kept in mind, as the life of the machine depends to a considerable extent upon whether or not it can be kept thoroughly oiled. Often all the necessary oiling provisions are made, but they are not in as plain sight as they should be and for this reason are likely to be overlooked.

Again, the oil holes should be well protected from dirt, and should also be easy to clean. Fast running machinery and that which needs oil constantly should be provided with good, self feed-

Plate 3. Machinery loses much of its value if kept in an agent's back yard for several years.

ing oil cups. Hard oilers have proven very satisfactory, especially where the parts are subjected to a great deal of dirt and there is no question but that they should be used even more than they are at present.

Thoroughly Painted.—The new implement or vehicle, as it comes from the dealer, should show a good grade of paint. This is especially true of buggies and wagons. The paint should show that it has been applied in smooth thin layers, which have been well rubbed down, and should not show a tendency to clottiness or scaliness. The paint should be covered with a good coat of varnish.

The character of the implement or vehicle is reflected to a

certain extent by the paint which covers it. Certain implements are known by their good paint, others are known by their poor paint.

New Machinery.—In buying new machinery or implements, the farmer should see to it, that he is not paying the price of a new machine for one that stood in an open back yard of some implement dealer, from one to three years. This is often the case and there is no good excuse for it from either the standpoint of the dealer or the farmer.

In the first place, the dealer should not allow his new machinery to stand in the open for long periods, and thus let it become weather beaten and damaged. In the second place, the farmer should not buy this damaged machinery at new machinery prices. He must consider that an implement is damaged as much by standing out one year, as it would be by actually using it one season.

PROPER ADJUSTMENT AND REPAIRS.

Adjustments.—Nearly every one understands the importance of making proper adjustments on farm machinery. A large percentage of the machines found in the field are badly out of adjustment. In many cases the improperly adjusted machines do such inferior work that they are discarded long before they are worn out.

For example, on one of the farms investigated, a binder, of reliable make, was found which had cut but ten acres before being discarded eight years ago, simply because the operator was unable to properly time the binder driving gear, after he had removed the cog wheel to replace a defective spring. The same make and type of binder has been in active operation on another investigated farm for the past twelve years. It has cut at least nine hundred acres and is still in first class condition.

The improper adjustment of one part of a machine often leads to the ruination of several other parts, much time of man, team and machine is lost "tinkering" with improperly adjusted machinery. In a large percentage of cases, the draft of the implement is unnecessarily increased because of improper adjustment. Not only is the draft increased, but it is not uncommon to find side draft produced in the machine as a result of improper adjustment.

The loss due to the discarding of machines before they are worn out, the inferior work, the damage to teams from excessive draft and side draft, and the valuable time lost in "tinkering" always justifies the spending of sufficient time to put the farm machinery in proper adjustment before it is put into regular service. Many of these adjustments may be made long before the machine is needed.

Repairing Machines.—Every machine, in active operation will sooner or later need repairs. The operator should be able to forsee the need of a large part of the necessary repairs some time before

they are actually needed. Of course, in the case of parts that break unexpectedly, due to defects or accidents, the operator has a reasonable excuse for not forseeing the trouble. But in cases where parts are worn, or weakened, there is little excuse for not making repairs long before the machine is to be operated again. In some cases it may be desirable to operate the old part for some time after it is badly worn. Under such conditions, good judgment demands the keeping of the extra part on hand ready to be substituted when occasion demands. As a worn part often ruins some unworn part, it is often advisable to replace the badly worn part at once. The main gear on a binder is an excellent example of the last mentioned case. After the pinion becomes worn, it is likely to either cut out the gear wheel or slip cogs, thus endangering chains and other gears.

It is advisable to place a tag upon each machine at the end of the season, stating just what repairs and adjustments are needed, so that these may be secured or made during the time when work is not pressing.

The investigation, which was carried on in May and June, showed that out of 1,716 machines (not including any discarded machines) 60.6 per cent were not in need of repairs. 27.15 per cent were in need of repairs according to statements received on the farms. The investigator could easily see, without careful examination, that 18.6 per cent of the machines needed repairs that were not reported. On 109 or 6.35 per cent of the machines the investigation showed that repairs in addition to those reported on the farms were needed. (The discrepancy of 6.35 per cent is thus explained.)

Sharpening.—There is little doubt in the minds of experienced farmers but that dull implements do an inferior grade of work, and at the same time, they unnecessarily increase the draft.

In general, with the exception of the smoothing harrow, the implements investigated proved to be as sharp as could reasonably be expected. Plows, disc harrows, cultivators and weeders were found to be in first class condition so far as sharpening was concerned. On the other hand, the smoothing harrow, one of the most important of farm implements, was found to be too dull for good service in 77 per cent of the investigated cases. Nearly 7 per cent of the harrows were too nearly new to be badly dulled, while only 16 per cent of the harrows had had the teeth reversed or sharpened. In the records of the dry farming sections over 83 per cent of the harrows (not including new ones) were sharp. In a great many cases, all that was necessary was the reversing of the teeth in order to give all the advantage of the sharp harrow, yet in only a few cases had this been done.

The investigation discovered harrows which had been in use for twenty years, and which had covered 3,000 acres without being sharpened or reversed.

Plate 4. It costs no more to do good work with a sharp harrow than it does to slide over the ground with a dull one.

THE FARM WORK SHOP.

If the observer was to draw conclusions from the farms investigated, he would have to conclude that very few farmers realize the importance of the farm work shop. As a matter of fact, a great many of those farmers who do not own shops understand the advantage of them. Again, many farmers are under the impression that they haven't the "knack," which they believe is a necessary adjunct, if they are to do repair work. Many have not investigated the cost of a small shop outfit, neither have they figured the matter on a basis of dollars and cents.

In cases where farmers are not very handy to the local shop, the time which is lost while going to and from the distant shop often amounts to several times the actual charges. At critical times, such as harvesting or seeding seasons, one long trip to town for repairs may cause a loss more than equal to the value of a well equipped shop.

The following table shows that the machinery found on farms having well equipped shops is in need of less repairs than that on farms without shops:

	Farms without Shops	Farms with Shops
Percentage of machinery not needing repairs.....	59.25	71.36
Percentage of machinery needing repairs as reported by the farmer.....	27.7	22.4
Percentage of machinery needing repairs as reported by investigator and not by farmer.....	20.2	6.24
Percentage of machinery reported by investigator needing repairs in addition to those reported by the farmer	7.15	0.0

The fact that machines are found in a better state of repair on the farms having well equipped shops goes to show very plainly that there is a real value to the shop beyond the occasional emergency job. These facts in themselves are strong arguments in favor of the farm shop. Of the farms investigated a little over 9 per cent were equipped with suitable shops.

Equipment.—In order to obtain the best results, the shop should be fitted with both carpenter and blacksmith tools. It should be handy to the place where the implements are stored, and some means of heating it in winter should be provided. A very serviceable farm carpenter equipment may be procured for less than $20.00 as follows:

One—grindstone and frame.	one—¼-in. bit.
" —oil stone.	" —⅜-in. bit.
" —good square.	" —½-in. bit.
" —fine cross cut saw, at least 24 in. long.	" —⅝-in. bit.
	" —¾-in. bit.
" —rip saw at least 26 in. long.	" —1-in bit.
" —compass saw.	" —¼-in. firmer chisel.
" —claw hammer.	" —½-in. firmer chisel.
" —Jack plane.	" —1-in. framing chisel.

One good, adjustable brace, strong enough to operate drills as well as bits.

In case the shop equipment is to be more nearly complete, a coarse, cross-cut saw may be added. A full set of bits, including an expansion bit, may be substituted for the above list of bits and a full set of planes will be found handy at times. A carpenter's combined level and plumb will be useful as will also a wood bench vise. The bench is easily constructed upon the farm.

In the line of blacksmith tools a great deal of difference of opinion exists. A small forge and anvil usually prove satisfactory, although some insist on large forges and heavy expensive anvils. It is safe to say that a serviceable farm blacksmith equipment as listed below may be secured for $30.00.

One small, combined portable hand blower and forge.
Two pairs tongs.
One hardy.
One steel-faced anvil.
One set of screw plates and taps, in sizes ¼, 5/16, ⅜, 7/16, ½, ⅝ and ¾ inches.
One triangular file about 6 inches.
One round file 10 inches.
One flat plow file about 14 inches.
One blacksmith hammer.
One combined vise and drill press.

By using the tools furnished with the farm machinery, in connection with the above enumerated outfit, a great deal of very good repair work may be done.

In case more money is to be expended, a strong blacksmith's

Plate 5. A Small Farm Shop

vise and a separate drill press fitted with twist drills should be substituted in place of the combined outfit. A complete set of screw plates and taps, ranging from one-fourth inch to one inch will be found useful. A heavy blacksmith's hammer and sledge will also come in handy. On large ranches the tire shrinker soon pays for itself.

LUBRICATION.

One of the first steps toward properly oiling farm machinery is to select it with good oiling provisions as described under "Oiling Devices."

Someone says: "Oil is the cheapest machinery we have." It

is better to spend fifty cents for oil than to spend $5.00 for a new part.

Application.—Surfaces of the wearing parts of a bearing must be covered with a thin film of oil to prevent cutting and to lighten the draft.

A bearing does not have to be "swimming" in oil in order to be well lubricated, but oil should be applied often in small quantities and should reach the place which needs it. All oil holes must be kept open and free from dirt. Sometimes they become clogged, and while they may appear to be open, still they do not convey the oil to the wearing parts and a great deal of damage is done. Many machines have been condemned, simply because one or two oiling places have been entirely overlooked. Often, for lack of a few drops of oil, the entire machine is brought to a standstill.

Kind of Lubricant.—There are many good grades of machine oils or lubricants on the market. There are also many poor grades of lubricants which are adulterated with rosin or paraffine, and may appear to be of excellent quality, but they are too gummy and dry up in a short time. Good oils will cost a little more than the cheap oils, but the higher priced oils really cost less in the end.

For farm purpose oils may be classified into heavy oils, light oils, cup grease or hard oil and axle grease. These do not necessarily include gasoline engine and steam engine oils.

The heavy oils are thick or viscous and are adapted to use only in such places as drive at slow speeds and carry heavy weights, as axles of wagons. The heavy oil is not easily forced out of the bearings and it lasts longer.

Light oils or thin oils come in several grades. For ordinary farm machinery, a medium thin oil will answer a large share of the needs. For high speed, light running machinery, such as cream separators, a thinner oil is used than that advisable for ordinary farm machinery. This oil is not adapted to machinery that carries heavy loads as it will squeeze out of the bearings too easily.

Cup grease or hard oil has many qualities to recommend it. It remains on the bearing very well, and is easily applied and can be used in place of heavy and medium oils. It is usually applied through an automatic compression cup or a hand screw cap cup.

In using hard oil, dirt cannot enter the bearing with the oil, in fact, if any dirt enters the bearing from the end, the oil will force it out. Again, if the bearing should begin to heat, the oil will begin to melt and feed faster, if the grease cup is placed above the bearing.

For gasoline and steam engine cylinders, special cylinder oil must be used. Gasoline cylinder oil is lighter and thinner than

steam engine oil and is less expensive. The cylinder oils must be able to stand a great deal of heat. A good grade of ordinary machine oil will lubricate all parts of the engines, excepting the cylinders.

Oiling New Machinery.—On account of paint in the bearings of new machinery, the moving parts often run hard for the first few days. This paint can be easily removed by the application of kerosene or a mixture of equal parts of kerosene and machine oil, as the machine is being started.

CARE OF MACHINERY WHEN NOT IN USE.

To properly care for the farm machinery means that it must be well selected, kept in good repair and adjustment, oiled thoroughly, cleaned before housing, and it must have all wearing parts well greased when not in use, and painted when necessary, and it must be properly housed.

At least one-half of "good care" consists in keeping the machinery properly repaired, in good adjustment and thoroughly oiled when in use. To neglect any of the lines of care mentioned, means serious damage and loss to the machine.

The investigation showed that a small percentage of the farmers were taking the proper care of their machinery all the time. Certain farmers were found who gave their machinery excellent care when it was in use but it was given no care between seasons.

The investigation shows that there is a decided tendency to neglect the housing of machinery throughout the State. On but 22.15 per cent of the investigated farms was all the machinery housed. It was partly housed on 39.60 per cent of the farms, and on 38.25 per cent of the farms no attempt was made to house any of the machinery except the buggies, carriages and automobiles.

With the one exception of binder canvasses only 2.01 per cent of the farmers removed bright or delicate parts of their machinery for storage.

The fact that such a large percentage of the machinery is allowed to stand in the open is partly, but not wholly, explained by the marked scarcity of suitable machine sheds upon the farms.

Of the investigated farms only 19.46 per cent were equipped with closed machine sheds. 34.23 per cent had some form of open shed and 46.31 per cent had no machine sheds at all. In 74 per cent of the open sheds the machinery served as a hen roost while the chickens were allowed to roost in but 31 per cent of the closed sheds. Hogs, calves, etc., were allowed to run at will in 19.6 per cent of the open sheds and in only 10.3 per cent of the closed sheds. The fact that in 62.5 per cent of all the sheds investgated the machinery served as a hen roost, and in 15 per cent

of the total number of sheds the farm animals were allowed to run at will, will explain to a large extent why the housing of machinery apparently does so little good in Colorado.

In a large number of cases the housing consists of "going through the motions" rather than actually preparing the machinery for storage and then properly storing it in a suitable shelter.

MACHINERY SHOULD BE CLEANED AND OILED BEFORE STORING.

Whether the machinery is to be housed or not, it should be cleaned and thoroughly oiled at the end of the season. With such machinery as the binder or mower, it is a good plan to thoroughly oil all bearings and wearing parts just before finishing the season. After removing all dirt, wipe the entire machine with an oiled rag or waste. The wearing parts especially should be well greased with tallow or axle grease. If the entire machine is to be housed these wearing parts do not need to be removed from the machine, but they should be removed and stored in a dry place under all other conditions.

HOUSING THE MACHINERY.

To house machinery does not always do as much good as is commonly supposed. In making the investigation, the following question was asked many times: "How should farm machinery be cared for?" It is usually answered by the farmer: "Everyone knows that it should be housed." This is a good answer as far as it goes, but to house machinery under any condition, and not properly care for it otherwise, constitutes very poor care.

Machinery may be just as well cared for if it is allowed to stand in the shade of a tree, as if it is stored in some of the leaky sheds, open sheds, poorly drained sheds, or combined machine sheds and hen roosts, such as were found during the investigation.

There is no question but that to properly house machinery is a great saving, as it not only adds a great deal to the life of the machine but it also adds to the general appearance of the farm. It was generally found that where a farmer was interested enough in his machine to properly house it, he was also interested enough in it to care for it otherwise.

The investigation showed that the life of farm machinery depended a great deal upon the owner. Individual farmers were found who took very good care of their machinery and left it in the weather, when not in use; others were found who gave their machinery very poor care and housed it when not in use. A great deal of housed machinery was found which had done no more work and was no better or older than some which had not been housed but which had been well cared for otherwise.

Cultivator shovels, plow shears, and attachments, which have been removed and greased, should be placed where there is no

chance for them to get damp. It is a good plan to place them in a gunny sack and suspend them from the rafters of the shed or barn.

A great deal of farm machinery can be placed in a small space if properly arranged. At the time of storing the machinery, it should be placed in the shed according to the time it will have to be removed. The machinery that will be used late during the following season should be placed in the back part of the shed and that which is to be used early in the season should be placed in front. In this way, it will not be necessary to remove a great deal of machinery in order to get what is needed first.

The following illustration gives an idea of the amount of machinery which may be stored in a small shed if the man who stores it studies the problem thoroughly.

The following list of machinery was found in a two-story shed 20x30 feet. The shed has a small side door and a large double door at one end. On the first floor: A set of blacksmith tools with bench (repair work is done in the shed), riding plow, 2 cultivators, beet cultivator, binder, mower, grindstone, hay rake, grain drill, 2 smoothing harrows (2 sections each), slip scraper, and lister. On the second floor: A hay tedder (taken apart), several light tools, stoves (stored while not in use), some household goods, and other articles to numerous to mention. In case of large crops, grain is sometimes stored on the second floor of the shed.

The owner of the above described shed unhesitatingly states that the shed is plenty large enough for the implements on 160 acres, providing the wagon and buggy can be stored in some other building.

The time required for storing this machinery and removing it each year is estimated by the farmer to be one-half day for himself and hired man.

As the machinery is being stored, all that which needs repairs or paint should be labeled so that it cannot be overlooked during the time when the farm work is not crowding.

PAINTING FARM MACHINERY.

There is no question but that it pays to keep the farm machinery thoroughly painted. This is especially true with such machinery as is largely constructed of wood. The paint fills all pores and cracks, prevents checking, prolongs the life of the machine and also adds very much to its appearance. Two or three dollars' worth of a good, reliable, ready-mixed paint for outside use, or carriage paint, applied each year to the machinery found on the average sized farm will add many times the cost of the paint to the value of the machinery.

THE IMPLEMENT HOUSE.

It is not always necessary or advisable to construct a special building for storing farm machinery. Often a very good place can be made in the barn or other buildings. By taking some of the parts off of certain machines, they can be easily stored in what otherwise might be waste space.

The characteristics of a good implement shed are:

1. It must be thoroughly drained so the implements do not stand in a wet place.
2. It must protect against sun, wind and moisture.
3. It must not be too expensive.
4. It should be located in a convenient spot and so arranged as to be easily used.

The material from which the shed is made will depend upon the cost and the locality. In the investigation, very good sheds were found which were of wood frame construction, covered with sheet iron. Other good ones were found of wood frame construction, sided with barn siding, drop siding, and in some places with ship-lap. Shingles or corrugated iron generally make the best roofs for machine sheds.

Description of Shed Shown in Plates 6 and 7

This shed was built on a Colorado farm and has been in use for several years. The owner makes a practice of storing his machinery as it should be.

Plate 6. An Excellent Closed Machine Shed. For plans see Plate 7.

The shed is built upon posts which rest upon concrete bases 12 inches by 12 inches. A strong iron dowel pin set in the concrete and projecting up into the post keeps the latter from slipping. The sides of the shed are 8 feet high. The roof is one-third pitch, shingled. Rafters 2 in. x 6 in. x 3 ft. on center. The lower girt is 2 in. x 6 in., the middle girt (placed just below the windows) is 2 in. x 6 in., while the upper girt is 2 in x 8 in. and serves as plate.

As the posts do not extend into the ground, it is necessary to brace the sides and ends of the shed. Braces also extend from the side posts to the collar beams, where the rafters come nearly over the posts. On the south side at the west end is a rolling door 7 feet 6 inches high by 8 feet long. At the east end the opening is 8 feet high by 10 feet wide. It is covered by two rolling doors 5 feet by 8 feet.

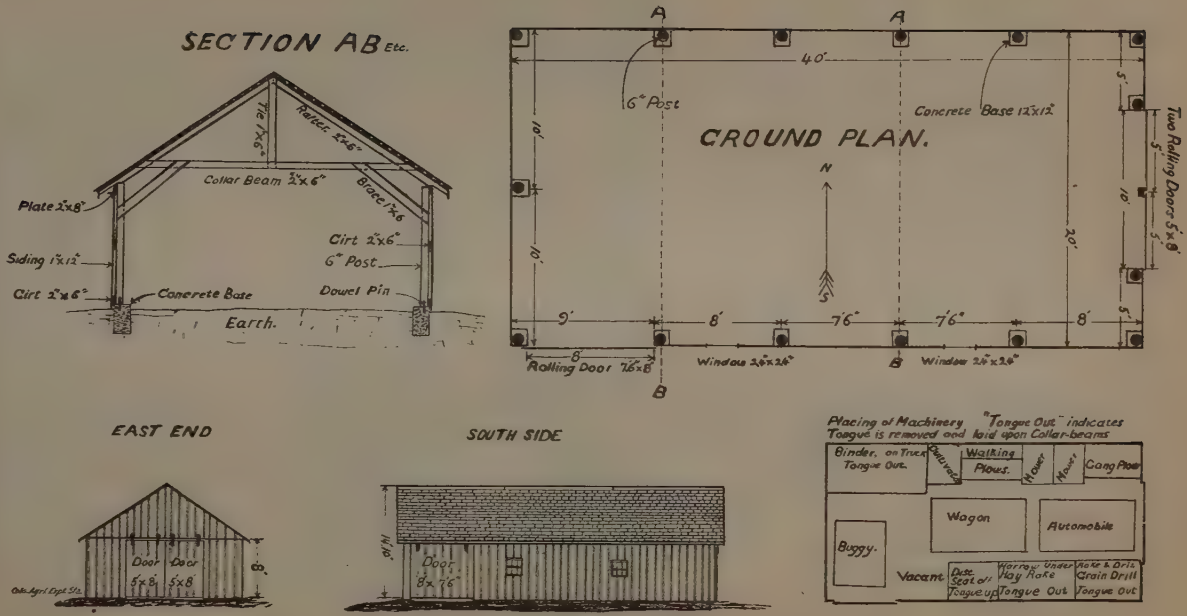

Plate 7. A Very Good Type of Closed Machine Shed

The sides are made of 12 inch stock boards. The cracks are covered with O. G. battens. The ground upon which the shed sits is about a foot higher than the surrounding ground. This gives a hard, dry dirt floor for the machinery.

In the lower right hand corner of the drawing is shown the arrangement of the machinery in the shed. In some cases (marked "tongue out") the tongues are removed from the machines and placed upon the collar beams. The cultivator shovels, mower sickles, plow shears, binder canvasses, etc., are all greased and suspended from the collar beams. A large part of the machinery may be removed by simply running out the auto. In some cases the wagon must also be removed. The transport trucks are almost a necessity for the storage of a binder in this sort of a shed. The shed is painted with two coats of mineral red in oil.

Description of Shed Shown in Plates 8 and 9

This shed has actually been built by a Colorado farmer and proves very economical and satisfactory. The only changes in the original plan is the addition of four small windows. The shed is 16x66 feet. The posts are 10 feet high in front and 8 feet high in the rear, and are set in the ground 3 feet. There is no foundation for the shed.

Plate 8. A Well Planned Machine Shed. For plans see Plate 9.

These posts eliminate the necessity of a frame or braces. The bottom girt is 2 in. x 6 in., the middle girt 2 in. x 4 in., and the top girt, which also acts as plate, is 2 in. x 8 in. The rafters are 2 in. x 6 in., set 3 feet apart on centers. The sheathing is 1 in. x 6 in. placed at the ends and in the middle of the sheets of corrugated iron which form the roof. At each end on the front side of the shed is located a 12 foot rolling door 8 feet high. Near the middle of the shed is a 14 foot door 8 feet high. These doors roll upon a continuous track which runs the entire length of the shed.

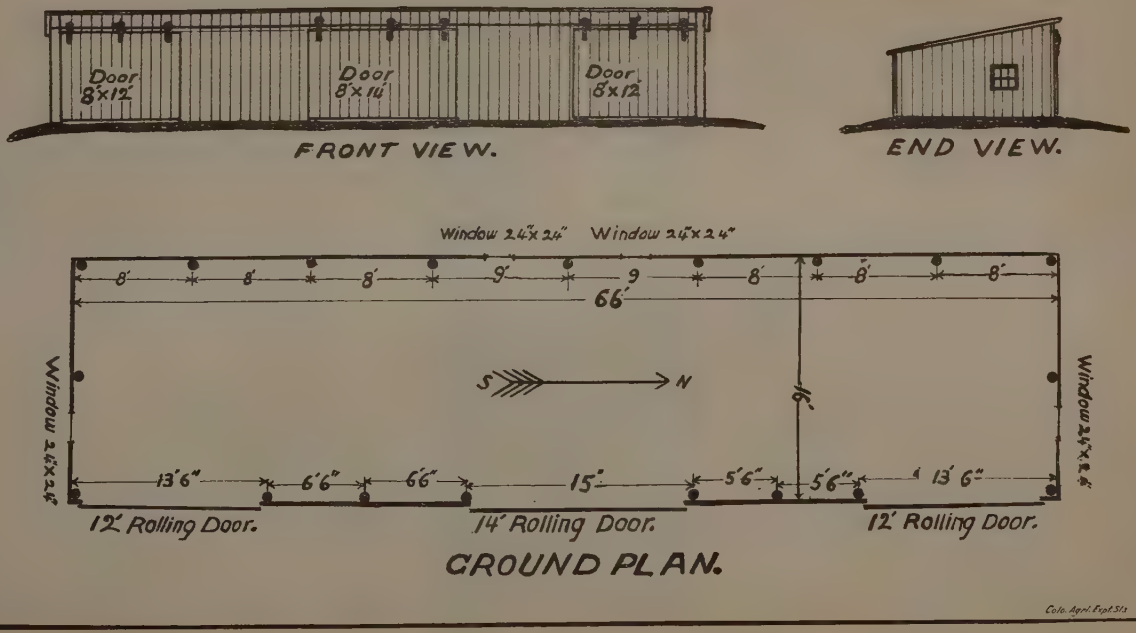

Plate 9. A Very Handy Shed with Corrugated Iron Roof

It becomes necessary to use a 2 in. x 8 in. plate and a 2 in. x 8 in. girt just above the doors to carry the weight of the doors.

The ground upon which the shed sits is about 8 to 12 inches higher than the surrounding ground. This gives a dry earth floor for the machinery.

In the drawing all the doors are closed. In the cut they are opened slightly.

The shed is painted with two coats of white lead in oil.

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BY

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AND

EARL DOUGLASS

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THE DETERIORATION OF MANURES UNDER SEMI-ARID CONDITIONS.

By W. P. Headden and Earl Douglass.

INTRODUCTION.

For many years prior to the introduction of the sugar beet as a commercial crop it was the practice of most Colorado farmers to throw away the manure made upon the farm. The land seemed to be inexhaustibly fertile and work spent in spreading manure upon the land was considered labor wasted. In the early years of our agricultural development, this was, to a certain degree, true. The soil gave bountiful crops year after year, and any additional fertility seemed to do more harm than good by increasing stems and leaves at the expense of grain. During these years the manure, much of it first-class sheep manure from sheep which had been fed upon corn and alfalfa, was dumped into the creek beds or sloughs, or left upon the ground, and the corrals were moved when the layer of manure became so thick that the sheep were likely to jump the fence.

Manure of More Importance than Formerly.

The growing of sugar beets and more intensive methods of farming have changed this, and in those districts in which there are sugar factories, the manure is now carefully saved and spread upon the land. More thought is given to saving the manure and to increasing the supply by fattening cattle or sheep on the farms, the value of the manure being now taken into account as part of the profits. There are still too many places in Colorado where the soil is being robbed, while the means of restoring, or at least partially restoring the fertility is going to waste in neglected manure heaps.

The question of the deterioration of manures under our Colorado conditions is important for the reason that the high freight rates make it impracticable for the western farmer to use the commercial fertilizers which are in common use in sections nearer the great distributing centers, the sea ports and packing houses. In the west, very little attention has been paid either to the subject of fertilizers or barnyard manures and, so far as we know, no analytical data are at hand on the deterioration of manures under semi-arid conditions.

Fresh Manure Should Not be Used on Irrigated Soils.

Another question arises, when discussing the deterioration of manure, namely, the effect of fresh manure upon soils which are sometimes watered scarcely enough to produce a crop. In order to prevent waste of the elements of fertility under humid conditions, the general practice has been to use the manure as fresh as possible.

It probably seems improvident on the part of our farmers to

have left the manure on the farm unused, but this was not wholly due to ignorance or to unwillingness to expend the labor necessary to apply it. The application of fresh manure to irrigated soils involves serious questions which are mentioned in this place merely to explain what must seem to most readers an irrational practice. Many inquiries among practical farmers brought out the fact that there are apparently good reasons for not applying fresh manure, namely, the manure does not rot and produces what is designated as "burning," by which they mean that manured land dries out quickly and the crop suffers. In fact the manure sometimes does more injury than good.

The Samples Studied.

The studies began in 1903 and 1904 during which time all the samples were collected and a large part of the analytical work finished. All the samples came from the vicinity of Fort Collins. Up to this time manures had not been used to any great extent except on small truck farms, lawns and gardens. Many car loads were shipped to Denver and it was a common sight in northern Colorado to see large piles of excellent corn-fed sheep manure left in the waste places of the farm to weather away. While the practice heretofore common among our farmers has been wasteful, the general result was to present an excellent opportunity for the study of the changes which had taken place in the manure due to the exposure to high winds, strong sunshine, and occasional heavy rains. There was no trouble at that time to get sheep or cattle manure of almost any age up to ten years and often even older, one lot being found which was twenty-seven years old. This was not the case with horse manure which, in our dry climate, fire-fangs badly. One instance came under our observation of a pile of horse manure taking fire spontaneously. For this reason practically no horse manure more than a year old can be found and that which has attained the age of a year and has lain in large heaps is simply a mass of dry, blackened stems, having very little value as a manure.

Waste of Liquid Manure.

Where so little attention is paid to the production of manure, no composting is done and the term "manure pile" simply means the pile of manure as it is thrown out of the barn or scraped out of the corrals. It generally contains only such bedding as was put into the stalls or corrals to keep the animals clean and not with the idea of absorbing the liquid manure or using straw as a part of the future fertilizer. No attempt whatever is made to use the liquid manure. If the barn can be so located that the urine runs away into a gutter or sewer, or if

by means of a bed of sand the stall can be kept reasonably dry, the barn is that much better in the estimation of the average Colorado farmer. Even though the cultivation of the sugar beet has caused some improvement in our practice, still too little regard is paid to the saving of the urine, a very valuable, perhaps the most valuable portion of the manure. In the feeding corrals, this is not quite true for much of the urine is absorbed by the solid portion of the manure.

The Older Samples of Sheep Manures.

Some of the older samples came from corrals where sheep or cattle had been fed some previous year but the present owner had followed other pursuits, leaving the corral with its bed of manure untouched. Many of the samples were from piles from four to sixteen feet in height made by scraping out the corrals preparatory to another year's feeding. All the sheep manures, with four exceptions, were from sheep which had been fattened for market and had therefore been fed as much alfalfa as they would eat and a very heavy ration of corn.

Importance in Amount and Value.

The corrals are, in most cases, open pens without shelter except occasionally a board fence to keep off the cold winds. Since the average farmer who fattens lambs, feeds between one and two thousand head for a period of about 100 days, the amount of manure is considerable. In addition, the manure must be more than ordinarily rich in plant food since as much as 95 percent of the potash, phosphoric acid and nitrogen are voided in the dung and urine from sheep on full feed. From the foregoing brief facts it will be seen that we are here dealing with a very rich manure and one which under ordinary conditions would be subject to rapid deterioration.

The Cattle Manure Not so Easy to Obtain.

The cattle manure samples were more difficult to obtain as the industry of fattening cattle had not been so generally practiced. There are, therefore, few samples of manure from corrals where cattle had been fattened, but as this is a growing industry, more and more of it will be produced and its preservation will become correspondingly important.

Sampling.

In case the manure was in the corral, the loose material was scraped off the surface and at least three sections, each about eight inches square, were taken at different places. A portion of the sample was put into a glass vessel and sealed to prevent drying out; the rest was preserved with ordinary precautions.

If the manure was in a pile, an average depth was selected and a hole dug into the pile from the surface to the ground. When a smooth vertical surface was obtained, a slice about eight inches wide and three inches thick was cut from the top to the bottom and placed in a bag. A smaller sample was placed in a fruit jar and sealed. Forty-five of these samples were collected during 1903 and 1904 but no manure pile or corral was sampled unless a fairly accurate history of it could be obtained.

The determinations of free ammonia and moisture were made on the freshly taken and sealed samples. The samples in the bags were air-dried, ground and sampled. Bedding is not used in the corrals unless there is mud, which occurs rather seldom in Colorado. The winter of 1903 and 1904 was particularly open and dry and no bedding was used; for this reason the samples called fresh manure were free from straw, while the older samples were probably nearly so.

Loss of Dry Matter on Weathering.

From the foregoing preliminary remarks, it will be seen that our study will, for the most part, have to do with analyses of manures of different kinds and of various ages gathered at about the same time. There is, however, another factor which must be known before any sharp conclusions regarding deterioration of manures can be drawn, namely, the loss of dry matter through weathering. Any one who has observed a pile of manure in a barnyard knows that it gradually diminishes in bulk and changes its appearance until it is finally difficult to distinguish the manure from the soil itself.

AN EXPERIMENT WITH SHEEP MANURE.

To determine the amount of this loss, ten tons of sheep manure were obtained from a corral where lambs had been finished for market by the usual method. The manure had received no moisture during the whole time of accumulation and was tramped into a hard cake about six inches deep over the whole corral. No bedding had been used although some alfalfa stems from the feeding racks were found in the manure. The ten tons of manure were put into a crib with a board floor on March 2d, 1904, making a heap about 3½ to 4 feet deep. The aeration of the manure in hauling and placing in the crib, caused very active bacterial action which manifested itself in two or three days. To check the heating and settle the manure, it was wet down thoroughly but not enough to cause water to run through the pile.

Ammonia is Lost Rapidly.

A few days after this the smell of escaping ammonia was very

strong, so strong that we tried to measure the ammonia by drawing air from the surface of the pile through normal sulfuric acid. A barrel was fitted with a stop cock in the bottom and used as an aspirator. Several flasks were filled with normal sulfuric acid and connected to a funnel, filled with cotton to prevent particles of manure from finding their way into the flasks. The funnel was simply laid on top of the manure pile and air drawn through the funnel and flasks by means of the barrel aspirator which held about 45 gallons of water or 6.015 cubic feet. When the water had all run out of the barrel, it was found that the flasks contained 0.0885 gram of ammonia.

An open dish of normal sulfuric acid with a surface of 67.2 square inches placed on top of the manure heap, absorbed 0.2606 gram of ammonia in 24 hours. This gives us some idea, vague though it may be, of the enormous loss of free ammonia. This fact has been observed over and over again and many ingenious ways have been used to show it, but each time we are astonished at the magnitude of this loss.

The Manure was Moistened.

Our object in this experiment was not to prevent all loss or even as much of it as is easily possible, but to determine the loss under ordinary conditions. The manure, however, was very dry and to prevent an extraordinary loss, it was thought best to wet it down thoroughly with the hose when first put into the crib. This was the only precaution used to prevent fire-fanging and was used only once.

On June 11, 1904, a hole was dug into the pile to see if any burning had taken place. There were some burned spots but the heavy rains had evidently kept the bacteria partially in check. There was a decided odor of ammonia and the manure was quite moist.

The First Weighing.

It was intended to weigh the manure at the end of the first year, but a long wet spell and work at the laboratory prevented until June 24th, 1905. On turning over the manure at this time, there was no odor of ammonia. The manure was well rotted and quite moist due to the recent rains. There must have been considerable loss from leaching as a rich brown liquid had oozed from the bottom of the crib and had run across the road in several places. A sample of each load was taken and after thoroughly mixing, two samples were drawn, one for the regular analysis and the other placed in a glass can and sealed for a determination of ammonia and moisture. The gross weight at this time was 20,595 pounds.

The Second Weighing.

The next weighing took place on May 18, 1906, and sample were taken as before. There had been heavy rains and the manur was again quite moist. There was no odor of ammonia.

Our Experiment is Stopped.

On March 20, 1907, when the time had come to reweigh the ma nure, it was found that by mistake a load of this manure had bee taken out and used in the greenhouses. Samples were taken fo analysis as before but the experiment was of course spoiled. It wa hoped this study could be extended over a period of about five years The results of the experiment are given in Table I.

Loss of Dry Matter as Determined by Other Investigators.

From many experiments conducted by Voelecker, with dung an litter, he concluded that from 30 to 60 percent of the original weigh of the manure was lost in the course of six to twelve months time This would indicate that our manure did not lose as rapidly as do thos in climates where there is a heavier rainfall and consequently mor leaching taking place. This fact is borne out by a comparison wit other experiments as given by Storer in his work on Agriculture, an also by many experiments for short periods of time, generally less tha a year. Taking these experiments as a whole, the loss in a year i about 45 to 50 percent, while the loss during this experiment was 32. percent in 15½ months, with a rainfall for that time of 26.18 inches which is much more than the average for this locality.

Character of the Loss in Semi-Arid Climates.

Leaching occurs where the rainfall is heavy and washes away muc soluble plant food, but helps to check the loss of ammonium compound while a dry climate prevents excessive leaching but destroys much nitro gen by volatilizing the ammonia.

Loss of Nitrogen.

Comparing the determinations of total nitrogen as they stand without taking into account the loss in gross weight which occurre during the first year, there has been a loss of one-third of the tota nitrogen, mostly in the form of free ammonia.

Taking into consideration the loss in weight of dry matter, ther is a total or absolute loss of 48.6 percent of the total nitrogen durin the first year—surely very startling figures to one who has not calcu lated the loss for oneself. The remaining manure is, however more valuable under our conditions than the original larger quantity

TABLE I.

DETERIORATION EXPERIMENT CALCULATED ON DRY MATTER.

Date	Weight in Pounds	Moisture Percent	Weight of Dry Matter	Loss Percent	Free Ammonia Percent	Total Nitrogen Percent
March 4, 1904	20.000	56.153	8,769	.....	1.483	2.713
June 24, 1905	20,595	71.255	5,920	32.487	0.543	2.067
May 18, 1906	12,540	69.743	3,794	56.730	0.187	2.010
March 20, 1907	.....	69.697	.....	.....	0.142	2.310

TABLE I, (Continued).

Date	Potassic Oxid Percent	Phosphoric Acid Percent	Soluble Ash Percent	Insoluble Ash Percent	Total Ash Percent	Sand and Silicic Acid Percent
March 4, 1904	3.892	1.172	6.180	16.756	22.936	8.222
June 24, 1905	5.999	1.004	8.890	22.030	30.920	9.239
May 18, 1906	6.012	1.102	7.468	28.560	36.028	10.678
March 20, 1907	6.189	1.072	7.695	32.040	39.735	12.082

because it can now be incorporated into the soil with advantage, and its humification may be completed in the soil while fresh manure may remain in the ground for years and produce objectionable results.

Loss in Two Years Found to be Less than Wolff Found in One Year.

The second year a further loss of 35.9 percent of dry matter occurred, making a total loss of 56.7 percent of the original dry matter in about two years. There seem to be very few experiments which extend over a period of greater length than one year, and we have consequently none with which to compare this loss. Wolff found that an 80-ton manure heap lost 65.5 percent of its dry matter in one year when exposed to wind and weather. This is much greater than our manure lost in two years. The total nitrogen decreased from 2.713 to 2.30 percent.

Loss of Nitrogen, Potash and Phosphoric Acid.

In order to compare the absolute losses to better advantage the results are calculated to pounds, and the losses given in percent. The original ten tons of manure contained 238.0 pounds of nitrogen, 341.3 pounds of potash and 102.8 pounds of phosphoric acid.

In June, 1905, when the original 8,769 pounds of dry matter had shrunk to 5,920 pounds, there were 122.2 pounds of total nitrogen, 355.1 pounds of potash and 59.44 pounds of phosphoric acid, or a loss of 48.64 percent of the nitrogen, and 42.17 percent of the phosphoric acid. The potash did not lose during the first year.

In May, 1906, the manure had further decreased in weight to 3,794 pounds of dry matter, and there were now present 76.27 pounds of nitrogen, 228.1 pounds of potash, and 41.81 pounds of phosphoric acid. This represents a total loss in two years of 67.95 percent of the nitrogen, 34.69 percent of the potash and 59.32 percent of the phosphoric acid.

In comparison with the losses from our manures, some instances of experiments at other Stations are here given, although it is a difficult matter to compare losses owing to the varying duration of the experiments and methods used.

Some Experiments at the New Jersey Station.

Dr. Voorhees in Bulletin 150 of the New Jersey Station, determined the loss sustained by 100-pound lots of cow manure when exposed to the weather in layers eight inches deep in a special form of galvanized iron box. From four experiments with mixed solid

and liquid manure for an average of 82 days, there was a loss of 51.0 percent of nitrogen, 51.1 percent of phosphoric acid and 61.1 percent of potash. Another experiment by Dr. Voorhees* gives as the results with solid and liquid manure exposed from February 4 to June 15, a period of 131 days, a loss of 57 percent nitrogen, 62 percent phosphoric acid and 72 percent potash.

A Difference in the Losses is Found.

Both of these experiments at the New Jersey Station, while dealing with a different manure under more severe conditions, show very much larger losses in 82 days and 131 days, than our sheep manure exhibited in over one year. This is particularly true of the potash which lost more rapidly than either the nitrogen or phosphoric acid in both the above experiments while, in our experiment with sheep manure, no potash at all was lost during the first year, and only 34.69 percent at the end of the two years. This is certainly a very remarkable fact and shows the very different character of losses in semi-arid climates. With us the heaviest loss is in nitrogen, while the chief loss under humid conditions is potash. This simply indicates the different manner in which the loss takes place. In the humid climate the loss a manure sustains is caused largely by leaching which dissolves the soluble salts, the principal one of which is potash. On the other hand the chief loss in semi-arid climates is nitrogen because it is easily converted into ammonia and lost during dry weather, while the loss of potash is small on account of the smaller number of drenching rains.

A Series of Experiments at the Cornell Station.

Roberts and Wing exposed horse manure loosely piled in a box, surrounded by manure, for a period of six months. The losses were 36.2 percent of the nitrogen, 50.0 percent of the phosphoric acid and 58.8 percent potash. At the same time the foregoing experiment was being tried, a solid block of horse and cow manure, taken as it had been compacted by the trampling of the animals, was exposed to the weather and the losses recorded were 3.2 percent of the nitrogen, 4.7 percent of the phosphoric acid and 35.0 percent of the potash†.

In an experiment the following year a two-ton pile of horse manure lost 60 percent of its nitrogen, 47 percent of its phosphoric acid and 76 percent of the potash. A five-ton pile of cow manure presented an apparent exception to the above three experiments by giving losses amounting to 41 percent of the nitrogen, 19 percent of the phosphoric acid and 8 percent of the potash. Professor Rob-

*New Jersey Report of 1899.

† New York Cornell Station Bulletins Nos. 13 and 27.

erts says of this result, "It is worthy of note that in this experiment the loss of potash was very slight in comparison with the phosphoric acid and nitrogen; in all of our other experiments the heaviest loss has been potash."

Director Peter Collier at the Geneva Station, N. Y. Bul. No. 23, New Series, with a well packed heap of cow manure containing 3,298 pounds, found a loss of 60.6 percent of the potash in one year.

Other experimental proof might be given but in almost every case where the manure is really exposed to the weather and not taken care of, the heaviest loss in a humid climate is the potash.

No comparable experiments with sheep manure were found. The only experiments at our disposal in which sheep manure was used were those of Muntz and Giard as quoted by A. Herbert in an article in the Experiment Station Record. In these experiments the manure was exposed for a period of six months with a loss of 25.04 percent of dry matter, 11.44 percent of nitrogen, 19.15 percent of phosphoric acid and 21.5 percent of potash. It is not clear from the article whether the manure was cared for or not, but one would surmise that it was probably packed in heaps in pits and the leachings pumped back on the pile. If this surmise be true, our conditions are not comparable, and the small losses recorded would be easily accounted for even though the climate of France, where these experiments were conducted, is much more moist than ours.

THE TWENTY-THREE SAMPLES OF SHEEP MANURE.

We will now turn our attention to the samples of sheep manure which were collected during 1903 and 1904. As has already been stated the sheep, or rather lambs, were all fed for eastern markets on corn and alfalfa, with four exceptions, viz. Nos. 31, 32, 34 and 36, in which cases the sheep were pastured during the day and kept in corrals at night, the object being wool rather than the fat lambs. The winter of 1903-04 was an exceptionally favorable one for the collection of samples as there was almost no rainfall during that time and the samples can be compared without allowance being made for leaching.

A Standard Analysis of Sheep Manure.

In order to obtain a standard for comparison, a large number of analyses of sheep manures, most of which are given in Storer's work on Agriculture, were averaged and recalculated to a dry basis as follows:

Average Composition of Sheep Manure.

	Moisture Included Percent	Calculated on Dry Matter Percent
Moisture	66.40	
Dry Matter	33.60	
Ash	7.35	21.875
Potash	0.86	2.559
Phosphoric Acid	0.38	1.131
Total Nitrogen	0.74	2.203

Notes on Table II.

Nos. 14, 15, and 16 were manures made during the winter of 1904 and the sheep had either been shipped or were nearly ready for market.

No. 17 was also made during 1904. This is a sample of the ten-ton lot which was used for the deterioration experiment.

No. 18 lay in the open corral until October, 1903. Smelled strongly of ammonia.

No. 19 lay in an open corral.

No. 20 lay in pile since May 1903.

No. 21 lay in open corral until September, 1903. Pile 3½ feet high.

No. 22 pile three feet high.

No. 23 lay in the corral 1½ years, then was scraped into a pile 8 feet high. Inside of pile quite warm but did not seem to be fire-fanged.

No. 24 pile 3 feet high.

No. 25 pile 3½ feet high.

Nos. 26 and 27 from different farms. Piles four feet high. In piles two years.

No. 28 pile 2½ feet high.

No. 29 two years in pile.

No. 30 pile 2½ feet high. Had been dumped near slough.

No. 31 sheep pastured on range during the day. Lay in an open corral.

No. 32 same as above except that it was under cover of a shed.

No. 33 had been put on top of other manure, but took only that which was four years old. Pile 5 feet high.

No. 34 pile 3½ feet high from same place as No. 31.

No. 35 had been hauled from the corral and dumped in a low, rather wet place.

No. 36 from a corral which had been used to shelter sheep which were pastured on the range. Manure about eight inches deep. Scraped off loose material before taking sample.

TABLE II.

PERCENTAGE COMPOSITION OF SHEEP MANURE, CALCULATED ON AIR-DRIED MANURE.

No.	Age Years	Moisture	Dry Matter	Soluble Ash	Insol. Ash	Total Ash	Sand and SiO_2	Potash	Phosphoric Acid	Crude Fiber	Free Ammonia	Total Nitrogen Fresh Sample	Total Nitrogen Air-dried Sample
14	Fresh	61.748	38.252	7.454	11.878	19.332	3.666	4.975	1.145	35.310	1.757	3.107	1.797
15	Fresh	59.638	40.362	10.218	14.892	25.110	5.828	3.594	1.211	33.370	1.724	2.894	1.745
16	Fresh	55.642	44.358	8.012	18.586	26.598	11.160	5.200	0.812	31.180	1.888	3.011	1.854
17	Fresh	56.153	43.847	6.180	16.756	22.936	8.222	3.892	1.172	33.805	1.483	2.709	1.847
18	1	54.873	45.127	7.352	36.544	43.896	28.134	5.617	1.299	27.440	1.680	1.935	1.430
19	1	63.573	36.427	9.744	12.942	22.686	5.051	6.919	1.157	40.010	1.715	2.385	1.331
20	1	50.047	49.953	8.762	32.294	41.056	23.582	7.873	1.104	36.525	0.156	1.831	1.673
21	1	47.923	52.077	7.217	38.743	45.966	25.220	4.858	1.010	27.760	0.437	1.715	1.529
22	2	58.735	41.265	7.377	49.231	56.608	35.510	2.522	1.784	16.780	0.080	1.865	1.552
23	2	55.478	44.522	8.217	34.052	42.269	22.980	6.218	1.118	23.280	0.546	1.698	1.400
24	2	58.680	41.320	7.998	38.798	46.796	10.420	8.987	1.052	30.065	0.499	1.657	1.405
25	3	61.623	38.377	8.586	29.822	38.408	19.723	6.149	1.419	29.530	0.886	2.110	1.465
26	3	52.613	47.387	8.734	43.202	51.936	32.106	5.622	0.841	20.545	0.509	1.542	1.672
27	3	58.302	41.698	7.080	58.210	65.290	17.828	4.862	1.197	6.890	0.017	1.511	1.633
28	3	48.180	51.820	5.916	57.005	62.921	44.331	5.332	1.112	12.265	0.073	1.556	1.410
29	3	53.527	46.473	7.084	40.964	48.048	28.159	5.525	1.224	24.485	0.138	1.679	1.586
30	4	65.958	34.042	8.969	33.926	42.895	18.969	1.854	0.760	27.045	0.444	1.559	1.637
31	4	40.629	59.371	5.964	49.418	55.382	36.622	5.172	0.710	9.480	0.047	1.592	1.533
32	4	24.239	75.761	7.220	45.196	52.416	32.990	3.543	0.687	16.560	0.156	1.524	1.552
33	4	62.817	37.183	13.638	25.822	39.460	15.270	7.371	1.360	26.300	0.212	2.157	2.262?
34	5	32.543	67.456	4.512	71.240	75.752	56.802	3.974	0.689	3.205	0.022	1.179	1.217
35	5-6	64.304	35.696	5.832	40.418	46.250	24.679	6.317	1.833	22.920	0.759	1.786	1.678
36	27	34.426	65.574	5.526	64.382	69.658	37.250	3.843	0.718	4.565	0.028	1.185	1.152

Influence of Feed upon the Value of Manure.

Since the feed has a great deal to do with the amount of plant fertility in the manure, this should be taken into consideration when discussing different manures. Most of the manures used in the standard analysis were from sheep fed on hays, beets, pasture and a few on alfalfa, but almost none were from feeding pens where sheep had been fattened and had received as much as they would eat of corn and alfalfa. The alfalfa being very rich in nitrogen of course produces a manure rich in that element also. The difference in feed is forcibly illustrated in Table II. The potash, phosphoric acid and nitrogen drop decidedly in Nos. 31, 32, 34, and 36, which are from sheep pastured on native grasses. No. 30 is also low in these constituents, but for another reason. It had been dumped into a slough and had every chance to leach out. The sample was taken with the idea that it was as badly taken care of as any which came under observation.

Our Manures Lack Moisture.

The most noticeable difference between the standard analysis and the analyses as given in Table II is the low percentage of moisture. Not one is as high as the average analysis, and but few approach it. The average of the moisture determinations given in Table II is 53.115 percent which is 13.285 percent below that of the average analysis. These figures bring prominently before us the fact that our manures are comparatively very dry.

Soluble Ash.

In dividing the ash into soluble and insoluble ash, it was thought that an increase in the soluble portion would be found as the manure increased in age. We know that the insoluble organic matter is being constantly changed in form and much of it rendered soluble, but from a consideration of Table II, one is forced to the conclusion that the soluble ash is rather a constant quantity, not varying much from the average, 7.7 percent, except in a few instances. In the deterioration experiment we had for the soluble ash:

Fresh Manure	6.180 percent
First year	8.890 percent
Second year	7.468 percent
Third year	7.695 percent

These results are also very close together and seem to show that the manure can hold about 7 percent soluble matter, the rest being leached out.

Results for Potash Differ from those in Humid Climates.

In discussing the potash in the ten-ton lot of sheep manure, it was pointed out that there was no loss of potash during the first year although the manure lost 32 percent in weight in that time. The determinations given in Table II corroborate the fact that the potash accumulated during the first year and are repeated below in order that this fact may be clearly seen.

Percent of Potash in Fresh Manures	Percent of Potash in One-Year-Old Manures
4.98	5.62
3.59	6.92
5.20	7.87
3.89	4.86
Average 4.42	Average 6.32

The results of the deterioration experiment were 3.89 percent in the fresh and 6.00 percent in the one-year-old samples.

After the first year the potash does not seem to accumulate further, and taking into consideration the loss in weight which occurs each year, there is an absolute loss from that time on.

Phosphoric Acid.

The phosphoric acid determinations are very close together varying very little from 1.2 percent with a few exceptions due for the most part to a difference in feed.

An interesting question arises as to the loss of phosphoric acid and the accumulation of potash during the first year. From what we know of the phosphates, they are as soluble as the potash salts and the loss of phosphoric acid can therefore hardly be accounted for by the leaching which took place.

Crude Fiber.

The crude fiber is a determination not often made on samples of manure, and does not appear to be of much value here as a criterion of either the age or the value of the manure. In a general way, the crude fiber decreases with age, but there is a wide range in the figures without any apparent reason for it.

Nitrates.

The question of nitrates in the manure did not come up until most of the samples had been thrown away. However, the results obtained

are of considerable interest as some of the samples gave abnormal amounts of nitrogen as nitrates. The following table gives the results obtained from those samples which had been kept.

Sample No.	Age	Percent N_2O_5
17	Fresh	None
17	1¼ years	0.465
17	3 years	0.752
15	Fresh	None
16	Fresh	Trace
18	1 year	0.371
21	1 year	0.108
25	3 years	0.287
26	3 years	1.610
27	3 years	0.821
31	4 years	0.188
33	4 years	2.151
35	5-0 years	0.093

The method used for these determinations was that of Schlosing and Grandeau as modified by Tieman and Schulze. Ten to twenty grams of manure were extracted with water and the filtrate and washings concentrated to a convenient volume from which point the above method, depending upon the reduction of nitric acid to nitrous oxid, was used. Precaution was taken in each case to absorb all carbonic acid by means of solid caustic soda in contact with the gas. To make sure that the gas was really NO, oxygen was admitted to the measuring tube a bubble at a time, and it was then found that all the gas oxidized readily and dissolved in water.

Voelecker* found only traces, not enough to determine quantitatively, of nitrates in either fresh or rotted manures. Holdefeiss also says that no nitrates are found when the manure is kept moist but that nitrates can form if the manure is covered with earth or is allowed to dry out. Holdefeiss found that as high as 8.5 percent of the nitrogen was present in a moist heap covered with earth, and an unmoistened heap carried as much as 18 percent of the nitrogen as nitrates.

The manure piles considered in this bulletin were, of course, not covered with earth and were not moistened except by the infrequent rains. The fresh manure contained none or doubtful traces of nitrates. In manure No. 17 there has been a steady increase in nitrogen as nitrates from none in the fresh manure to 8.5 percent of the nitrogen present as nitrates in the three-year-old manure. The other samples do not follow this increase with age, some being high and some very low in nitrates. Nor does the amount of nitrate present seem to be governed

*As given in Storer's Agriculture Vol. II. p. 319.

by the amount of moisture in the manure. The probability is that the conditions were right in some manures for the work of nitrifying bacteria. In other manures the nitrates had been washed away or nitrification had not taken place.

The three highest results, viz., Nos. 26, 27, and 33, have 27.13, 14.13 and 25.94 percent, respectively, of their nitrogen present as nitrates, which will be seen to be abnormally high as compared with Holdefeiss' figures.

The question might be raised whether nitrification had not proceeded in the sample cans in the laboratory. This was effectually settled in the case of No. 17. A determination of the nitrates in the three-year-old sample had been made in 1906 and a re-determination of nitrates in 1910 gave practically the same result. Air-drying the manure seems to stop most bacterial changes.

THE FREE AMMONIA.

The free ammonia in the manures which have been discussed in the foregoing pages offers a very interesting study not only because of the larger amount in fresh manures, but because it is the most easily lost of all the elements of fertility under our conditions. It has been pointed out that the principal loss from manures under humid conditions is potash but that the greatest loss in our climate is nitrogen. From the following discussion it will be seen that this loss occurs principally through a loss of free ammonia.

The bacterial changes taking place in the manure heap are very complex and not fully understood, but it is certain that among the first of these changes is the ammoniacal fermentation which first changes the nitrogen compounds of the liquid manure into ammonium salts, or allows the ammonia to escape into the air. Some of the ammonium salts are now oxidized to nitrites but are not changed into nitrates until all the ammonia has been dissipated or has combined to form neutral salts. The process is quickly completed in the liquid manure which contains organic nitrogen in a soluble form. The nitrogen in the solid portion is also attacked by ammonifying bacteria, but this change takes place slowly, which allows more time for the change into nitrates and nitrites. The great loss of ammonia from our sheep manures, however, must come from the comparatively swift change of large amounts of hippuric acid from the liquid manure into ammonia through the agency of uro-bacteria.

We know that most of this ammonia immediately combines to form ammonium carbonate, and being in this form it is peculiarly susceptible to changes in temperature and to the presence or absence of moisture. Now ammoniacal fermentation takes place most readily when the bacteria have a plentiful supply of air, warm sunshiny weath-

er, and comparatively dry manure. It is easy to see, therefore, why manures under our conditions lose so much of their nitrogen. The bright, almost continuous sunshine and drying winds, are the two greatest agents tending to dissipate this valuable element of fertility. Another factor which is responsible for great loss of ammonia is the way in which our manures are cared for, viz., the practice of scraping the manure out of the corral into a loose pile. Admitting the air into the manure heap in this way both dries it out and supplies a plentiful amount of oxygen which gives just the right conditions for intense aerobic activity, especially when the cleaning of the corrals takes place in the summer time, as is usually the case. If the manure was compacted and moistened thoroughly, or put into pits and the leachings pumped back on the pile, as is the custom in France, the loss would be negligible in comparison with the good done by the slower and less destructive anaerobic fermentation.

What has just been stated regarding the loss of ammonia from manure which has been loosely piled up is well illustrated by four samples from Table II, viz., Nos. 18, 19, 20, and 21. These manures are all one year old, but had been treated in different ways by the farmers who owned them. Number 18 was scraped into a pile the fore part of November, a few days before the sample was taken. Number 19 lay untouched in an open corral. Number 20 had been scraped into a pile in May, and Number 21 early in September. Samples of these manures were collected in November and analyzed immediately with the following results:

No. 18 ..... 1.68 percent free ammonia.
No. 19 ..... 1.72 percent free ammonia.
No. 20 ..... 0.17 percent free ammonia.
No. 21 ..... 0.44 percent free ammonia.

While they are of the same age, we see that Nos. 20 and 21, which had been scraped into piles, had lost almost the whole of their free ammonia. Number 18, which had been placed in a pile a little while before the sample was taken, smelled very strongly of ammonia and was therefore losing ammonia rapidly at that time and probably dropped from 1.68 percent in the course of two or three months down to the level to which Nos. 20 and 21 had fallen in a like time. Turning now to No. 19, which lay in an open corral compacted by the trampling of the sheep during the feeding time, we find 1.72 percent, the same amount of free ammonia found in the fresh manures. The lack of air practically stopped the action of aerobic bacteria and anaerobic fermentation had proceeded slowly within the layer of manure.

An objection might be raised that the difference in content of free ammonia was the result of unequal bacterial activity, and that more ammonia had been formed in No. 19 than in the others, but a comparison of the determinations of total nitrogen in the thoroughly dried samples, shows that the ammonia had been formed in equal amounts in these manures, but had been lost before being changed into a form which could be better retained by the manure.

This can be seen to better advantage by repeating the figures given in Table II for these four manures.

	Total nitrogen in fresh samples.	Total nitrogen in air-dried manure.
No. 18	1.935	1.430
No. 19	2.385	1.331
No. 20	1.831	1.673
No. 21	1.715	1.529

It will be noticed that all four manures have nearly the same amount of nitrogen in the air-dried samples, and since the sheep were all fed alike, at the same time and in the same way, it would be reasonable to suppose that these manures had over two percent of total nitrogen as they lay in the corrals and it was only when they were scraped out and aerated that the ammonia was lost.

Another factor tending to preserve the ammonia in No. 19 was the larger amount of water present.

No. 18	54.87 percent moisture.
No. 19	63.57 percent moisture.
No. 20	50.05 percent moisture.
No. 21	47.92 percent moisture.

No. 19 had not lost its moisture because it had been left undisturbed in the corral, and this was not due to a favorable location. The corral in which it was found was on top of a hill with no shade of any kind. No. 18 probably had just as much or more moisture as it lay in the corral a few days before, but in scraping it up and hauling to the pile it had lost about 9 percent as we are justified in concluding from the fact that comparable samples from the same farm contained 62 and 63 percent moisture.

Table II shows how dependent the percentage of free ammonia, and to a slighter degree that of the total nitrogen, is upon the water content of the manure. The more moisture in the manure the more free ammonia and total nitrogen is present. There are three samples, Numbers 18, 25, and 33 which came from the same farm. They were on the north side of a row of thickly set cottonwoods and the moist condition was noticeable at the time of taking the samples. Their larger percentages of total nitrogen, 1.935, 2.110, 2.157, show the

effects of the larger content of moisture which prevented a part of the loss of ammonia, or, which amounts to the same thing so far as the value of the manure is concerned, retarded ammonification, and allowed more time for the formation of ammonium salts. The moisture also helps check excessive heating, which dissipates much of the nitrogen as ammonia in a semi-arid climate.

Another prominent case in point is No. 35, with 64 percent moisture which, though five or six years old, has retained 0.759 percent free ammonia.

It will be noticed that the free ammonia amounts to about half the total nitrogen in the fresh manures and that there was a large loss on air-drying these samples. As we pass down the table to the older manures, this loss on drying becomes less until from No. 30 on there is scarcely any free ammonia, and practically no loss on air-drying, except in the case of No. 35 which was moist enough to retain 0.759 percent of free ammonia. This seems to indicate that at the end of about three years ammonification has entirely ceased, and the ammonium salts formed have either been lost or changed into nitrites and nitrates. It is probable that ammonification practically ceases long before this, especially when the manure has been disturbed and aerated.

The Loss of Ammonia in the Deterioration Experiment.

The "fresh" manure, or the manure as it was taken out of the corral, contained 1.48 percent of free ammonia, which makes 130 pounds in the ten tons of manure. At the end of 15 months there were but 32.2 pounds of ammonia. If no loss had occurred during this time our total nitrogen ought to be about the same in the sample when placed in the crib and again a year and a quarter afterwards, but we find that the total nitrogen has shrunken from 237.9 pounds in the ten tons to 122.4 pounds when sampled again, a loss of 115.5 pounds. We know that some leaching occurred during this time but it surely could not have been of much consequence when no potash was lost. The loss of nitrogen must, therefore, occur almost wholly through a loss of ammonia.

Furthermore, from a series of determinations of nitrates, as given elsewhere in this bulletin, there was present but 0.121 percent of the manure as nitrates at the end of 15 months. There might have been some nitrates present, but certainly not much of the ammonia had been converted into nitrates.

In all probability the greater portion of the work of ammonification had taken place and the 32 pounds of free ammonia obtained at the end of 15 months were simply ammonium salts awaiting nitrification. At the end of the second year there were but 7.1 pounds

of ammonia, showing that ammonification had now almost entirely ceased, if, indeed, it had not done so sometime previously.

The further loss of 46.1 pounds of total nitrogen during the second year points to the fact that ammonia was still escaping, though much less rapidly than in the fresh manure.

Another fact responsible at times for large losses of nitrogen is the presence of denitrifying bacteria which set free elementary nitrogen.

CARBON AND HYDROGEN.

Elementary carbon and hydrogen determinations were also made on these samples of manure, the object being to find out to what extent the carbon accumulated in the manure as it grew older. Theoretically it would seem as though the amount of carbon would increase as the manure is changed by the bacteria with the formation of soluble salts and setting free of gases. Since the insoluble ash accumulates with the age of the manure, this factor must be eliminated in the results. The percentages of carbon and hydrogen are, therefore, re-calculated which gives a better basis for comparison.

The re-calculated results present a remarkable series. Far from being a variable quantity or showing any accumulation with age, the ratio of the carbon to the hydrogen is as constant a quantity as if the material were a series of lignite coal samples rather than manures. The average gives a ratio of 33.6 to 4.9. The breaking down of the cellulose with the liberation of carbon dioxide has kept pace with other kinds of fermentation leaving the same relative amounts of both carbon and hydrogen present in the manure.

TABLE III.

Carbon and Hydrogen in Sheep Manures.

The results are in percent of air-dried manure.

		Sand and Silicic Acid Included		Sand and Silicic Acid Excluded	
No.	Age	Carbon	Hydrogen	Carbon	Hydrogen
14	Fresh	37.809	5.682	39.250	5.843
15	Fresh	33.110	5.021	35.160	5.332
16	Fresh	30.095	4.808	33.875	5.412
17	Fresh	29.011	4.803	31.610	5.331
18	1 year	24.712	3.649	34.385	5.078
19	1 year	34.521	5.276	36.358	5.557
20	1 year	25.130	3.575	32.884	4.678
21	1 year	25.695	3.668	34.722	4.905
22	2 years	23.623	3.110	36.630	4.823
23	2 years	27.291	3.792	35.434	4.924
24	2 years	25.942	3.560	28.950	3.974
25	3 years	28.686	4.069	35.734	5.069
26	3 years	22.580	3.092	33.258	4.554
28	3 years	16.910	2.276	30.376	4.089
29	3 years	25.398	3.443	35.344	4 792
30	4 years	28.680	3.776	35.394	4.660
31	4 years	22.450	3.195	35.423	5.041
32	4 years	25.215	3.483	37.630	5.198
33	4 years	27.624	3.968	32.602	4.683
34	5 years	12.600	1.609	29.169	3.725
35	5-6 yrs	25.471	3.590	33.816	4.766
36	27 years	12.748?	2.717	20.317?	4.431

THE CATTLE MANURES.

We will now turn our attention to the cow or cattle manures collected during the same winter as the sheep manures, but not presenting so continuous a series. To enable a better comparison, we give an average analysis which is obtained from about fifty analyses as given by Storer in his "Agriculture." Many of the analyses included in this average are of fresh manures, but this does not affect the results for they were not much higher in moisture than the old manures. This average represents manures as they are met with in moist climates.

Average Composition of Cow Manure in Percent.

	Moisture Included	Dry Matter Only
Moisture	74.66	
Dry Matter	25.34	
Ash	4.31	17.01
Potash	0.56	2.21
Phosphoric Acid	0.32	1.26
Total Nitrogen	0.57	2.24

TABLE IV.

PERCENTAGE COMPOSITION OF COW MANURES, CALCULATED ON AIR-DRIED MANURE.

No.	Age Yrs.	Moisture	Dry Matter	Soluble Ash	Insol. Ash	Total Ash	Sand and SiO_2	Potash	Phosphoric Acid	Crude Fiber	Free Ammonia	Total Nitrogen Fresh Sample	Total Nitrogen Air-dried Sample
1	1	31.534	68.466	5.275	54.315	59.590	41.885	5.151	0.629	18.235	0.229	0.914	1.080
2	2	69.230	30.770	5.595	47.597	53.192	36.988	3.647	0.727	20.445	0.397	1.624	1.101
3	3	39.109	60.891	4.612	60.616	65.228	48.285	3.965	0.660	15.840	0.035	0.558	1.005
4	10	66.081	33.919	7.676	39.208	46.884	25.977	6.899	1.482	24.375	0.316	1.661	1.665
5	10-12	49.110	50.890	3.189	58.133	61.322	43.865	3.511	0.808	16.075	0.022	1.147	1.135
6	3	65.732	34.268	9.992	37.814	47.806	22.954	6.665	0.939	22.575	0.665	1.825	1.484
7	½	38.490	61.510	2.300	39.946	42.246	32.553	2.599	0.702	18.480	0.057	1.415	1.424
8	½	54.328	45.672	7.966	32.188	40.154	28.494	4.022	0.839	14.550	0.261	2.220	1.851
9	1	76.112	23.888	5.469	35.654	41.123	27.743	4.030	0.776	24.300	0.092	1.740	1.538
10	2	57.380	42.620	4.434	48.024	52.458	39.500	3.639	0.958	4.325	0.141	1.523	1.369
11	2-5	44.218	55.782	2.552	52.776	55.328	44.600	5.588	0.794	7.995	0.023	1.606	1.542
12	10	48.736	51.264	3.730	56.830	60.560	45.160	5.201	0.984	7.500	0.084	1.405	1.347
13	18	35.978	64.022	.....	.....	72.344	64.651	5.396	0.687	2.685	0.015	0.941	1.014

Notes on Table IV.

No. 1. This manure was in a pile five feet high. The cattle were fed alfalfa hay.

No. 2. Manure was in corral one year and was then put in pile four feet high. The feed was alfalfa hay.

No. 3. This manure still lay on the ground in the corral. The feed was alfalfa hay.

No. 4. This manure was in a pile four feet high. The feed was alfalfa hay and corn.

No. 5. Only a small amount of this manure remained. The feed was corn, barley and alfalfa.

No. 6. This manure was in a pile four feet high. The feed was corn and alfalfa.

No. 7. This manure was from milk cows, pastured during the day on native mountain grasses. No grain fed.

No. 8. From milk cows fed as No. 7.

No. 9. This manure was in pile three and one-half feet high. The feed was alfalfa and timothy hays.

No. 10. This manure was made under cover of a shed, and had not been piled up. The feed was native, timothy and alfalfa hays.

No. 11. Same as above except that only native hay was used.

No. 12. This manure was undisturbed in a corral for two years and was then placed in a pile and remained there for eight years. The feed was native hay.

No. 13. This manure was from a pile which had weathered until it was but one and one-half feet high. The feed was native hay.

Moisture is Low in Cattle Manures.

A comparison of Table IV with the average analysis given shows a most striking difference in the moisture content, nor is this difference due to the inclusion of a number of fresh manure analyses in the standard analysis, for in an experiment conducted by the New York Station, Geneva Bul. No. 23, New Series, the moisture in the manure after one year's weathering is given as 75.18 percent. The average amount of water in the 13 manures given in Table IV is 52 percent or 22 percent less than in the average analysis. The cow manures are drier even than the sheep manures which had 13.3 percent less moisture than the standard analysis. Number 9, which has 76 percent moisture was from a pile under the eaves of a barn where it received the water from the roof during rainstorms.

There Was Some Difficulty With Sand.

The total ash is high compared with the average, but when the sand and silicic acid are subtracted, the results are very close to those of the standard analysis. One of the difficulties with a few of the older samples of the cow manures was the presence of large amounts of sand and gravel which had been blown or trampled into them. Literally a quart or two of gravel had to be picked out of some of the samples before anything in an analytical way could be done with them. For this reason the sand and silicic acid were carefully determined in the ash, although some of the silicic acid belongs to the ash of the manure as it was a constituent of the plants the animals fed upon.

The Soluble Portion is Nearly a Constant Quantity.

While discussing the soluble and insoluble ash in sheep manure, it was stated that the soluble ash did not increase with age, but remained near 7 percent. This is also the case with the cow manures, except that the soluble ash amounts to about 5 percent. This probably points to the fact that the manure can retain about that amount of soluble ash, the rest being lost through leaching. We know from many experiments, some of which have already been cited in connection with the discussion of sheep manure, that all manures lose rapidly in bulk and weight when exposed to the weather, and an increase in the ash content, soluble as well as insoluble, should take place, but we find that the soluble ash remains constant. The loss consists chiefly of soluble salts and liberated gases, such as carbon dioxide and nitrogen, caused by the action of micro-organisms. From the results given in Table IV, it would seem that almost the whole of these soluble salts are lost since the manure retains only about 5 percent no matter how old it is. This loss is principally due to leaching, for some of our rainfalls are heavy, and sometimes extend over a considerable period.

Solubility of the Nitrogen, Potash and Phosphoric Acid in Water.

It was so unusual to find the potash retained by the manure to a greater extent than the nitrogen, that 200 grams of manure No. 17 were extracted with water, and the potash and phosphoric acid determined in the extract.

After washing with water there remained 164.4 grams of manure making a loss in the extract of 17.8 percent. The nitrogen was determined in the residue and in the original sample, the former giving 1.817 percent and the latter 1.125 percent, a difference of 0.692 percent, which was the amount soluble in water. The phosphoric acid in the soluble portion amounted to 0.265 percent and the potash to 1.700 percent calculated on the air-dry manure. This shows conclusively that it was not because the potash was held as some insoluble

salt in the manure but because there had not been enough rain to wash out the potash during the first year. The above figures represent a loss of 43.7 percent of the potash, 22.6 percent of the phosphoric acid and 38.0 percent of the nitrogen, which correspond closely to the results obtained under humid conditions.

Potash and Phosphoric Acid.

Since the potash salts and the phosphates are among the soluble salts, we find they are among those lost by leaching. It was pointed out that the phosphoric acid in the sheep manure was lost at about the same rate that leaching occurred. This seems to be the case here as the phosphoric acid determinations run very close together with the exception of No. 4, which is probably high on account of the heavy ration of corn and alfalfa these cattle received. The potash determinations vary to a greater extent than those of the phosphoric acid, but to what this is due is a question. The cattle manures are much more unsatisfactory than the sheep manures, because so many different combinations of hays and grains fed are represented. The rich feed gives a manure rich in plant food, and this difference sometimes persists after years of weathering. The phosphoric acid and nitrogen are less than results given in the standard analysis, while the potash is much higher. This again emphasizes what has been said regarding the loss of potash from sheep manure, and corroborates the statement that the heaviest loss under our conditions is not potash but nitrogen. The average of 13 potash determinations is 4.64 percent, more than twice the percentage in the standard analysis.

There is, of course, an absolute loss of potash as the manure loses in weight through weathering. This loss probably begins at about the same time it did in the sheep manure, namely, after the first year, and from that time on, like the phosphoric acid, it is lost at about the same rate as the manure loses in weight.

The Nitrogen.

The total nitrogen is lower than in the standard analysis. The average of Table IV is 1.43 percent, while the standard analysis gives 2.24 percent. The standard analysis is composed of very much younger manures than those in Table No. IV, and it will be noticed that the only manure in the table, No. 8, having an amount of total nitrogen equal to the standard analysis, is but six months old. Since the total nitrogen is low compared with the standard analysis, the absolute loss must be very large. The loss of nitrogen on air-drying the samples follows closely the results as given under the sheep manures, i. e., the loss is heaviest where there is the most free ammonia. There are some results in which an apparent gain is

made on air-drying. The cow manures were much harder to sample than the sheep manures, and this probably accounts for some discrepancies in the results.

TABLE V.

Carbon and Hydrogen in Cow Manures.

The results are in percent of air-dried manure.

	Sand and Silicic Acid Included			Sand and Silicic Acid Excluded	
No.	Age in years	Carbon	Hydrogen	Carbon	Hydrogen
1	1	20.450	2.690	35.188	4.630
2	2	23.920	3.193	37.961	5.067
3	3	18.480	2.418	35.735	4.676
4	10	23.564	3.388	31.833	4.577
5	10-12	6.884?	2.698	12.263?	4.806
6	3	25.414	3.256	32.982	4.226
7	½	24.871	4.029	36.876	5.974
8	½	27.092	4.313	37.887	6.032
9	1	28.412	4.001	39.321	5.537
10	2	20.784	3.208	34.354	5.302
11	2-5	19.983	2.859	36.071	5.161
12	10	18.946	2.739	34.546	4.995
13	18	12.266	1.366	34.771	3.863

Table V, like Table III, gives a series of carbon and hydrogen determinations which are remarkably close together. The average of the carbon determinations with sand and silicic acid calculated out is 33.8 percent and the hydrogen is almost an even 5 percent. Now the ratio of the carbon to the hydrogen in the sheep manures was 33.6 to 4.9 which are about the identical figures for the cow manures. There is then practically a constant amount of carbon and hydrogen in both sheep and cattle manures.

Some Miscellaneous Manures.

Table VI contains those manures which were not all of one kind, but are rather to be classed as mixed stable manures. Two of the manures, Nos. 44 and 45, are horse manure alone.

TABLE VI.

PERCENTAGE COMPOSITION OF MISCELLANEOUS MANURES, CALCULATED ON AIR-DRIED MANURE.

No.	Age Yrs.	Moisture	Dry Matter	Soluble Ash	Insol. Ash	Total Ash	Sand and SiO_2	Potash	Phosphoric Acid	Crude Fiber	Free Ammonia	Total Nitrogen Fresh Sample	Total Nitrogen Air-dried Sample
37	2	64.224	35.776	7.344	38.500	45.844	27.260	6.106	1.175	26.825	0.808	2.024	1.373
38	6	50.749	49.251	3.507	68.763	72.270	57.190	6.140	0.684	11.555	0.181	1.204	0.832
39	4-5	55.623	44.376	6.184	42.005	48.189	25.820	3.622	0.976	23.155	0.095	1.387	1.499
40	10	58.897	41.103	6.007	42.661	48.668	26.271	3.302	0.972	26.575	0.136	1.661	1.485
41	20	57.402	42.598	2.746	58.935	61.681	45.800	6.203	1.353	7.720	0.035	1.908	1.313
42	3	52.115	47.885	2.327	55.049	57.376	45.730	5.106	1.055	7.250	0.027	1.520	1.417
43	6	40.344	59.656	0.910	68.102	69.012	59.741	2.214	0.560	2.360	0.020	1.149	1.104
44	Fresh	64.304	35.696	5.832	40.418	46.250	18.633	8.196	0.994	28.235	1.198	2.057	1.277
45	1¼	34.909	65.090	6.698	45.688	52.386	32.420	5.147	1.002	19.485	0.143	1.299	1.507

Notes on Table VI.

No. 37. Sheep and cattle. Pile 8 feet high. Very moist.

No. 38. Sheep and cattle. Pile 8 feet high.

No. 39. Sheep and cattle. In open corral undisturbed.

No. 40. Sheep and cattle. In open corral undisturbed.

No. 41. Horse, hog and cattle. In pile at least 15 years.

No. 42. Cattle and horse.

No. 43. Mixed stable manure. Considerable hay and dirt in the manure.

No. 44. Horse manure, made by work horses. Fed heavily on barley, bran, corn and alfalfa.

No. 45. Horse manure. Pile 6 feet high. Not much bedding used. Interior badly fire-fanged.

It will be noticed that the potash is high, and that the phosphoric acid runs about 1 percent. The moistures in the two horse manures are interesting in showing how this kind of manure practically burns up. At the end of 1 1-4 years there was only 35 percent moisture, and the whole interior of the pile was a mass of dry stems, so badly was it fire-fanged. It is rather surprising, however, to see how much nitrogen remained in the burned manure, although by far the greater portion of it had been lost.

Preservation of Manure.

Knowing at about what rate the manure deteriorates, and what elements of plant food are most easily lost, a few hints might not be out of place as to some waste which can be stopped by good management. Since the nitrogen, particularly as free ammonia, is the most easily lost in a dry climate, that is the substance we must preserve.

We have seen that piling up manure loosely causes intense bacterial action, and consequently loss of free ammonia. It will be best, therefore, to leave the manure in the corral until it can be hauled out and spread on the ground. If the corral must be cleaned, pile the manure in a shady place where its moisture will be retained. If at all possible and the weather is dry, moisten the manure with the hose after it has been placed in the pile; or, lacking any way of moistening the manure, try to clean the corral during wet weather.

Any method of compacting the manure pile to keep out the air will be found to help largely in conserving the nitrogen.

If both cattle and horse manure are produced on the farm, probably much of the horse manure could be rotted and yet not badly fire-fanged by mixing the two manures. Here, too, an occasional wetting would save much fertility.

Fresh sheep manure particularly should not be spread upon the land under our conditions, but rotting about six months, or at most a year, is all that is necessary to put the manure in fine condition for immediate assimilation by plants.

Recapitulation.

The main facts brought out by the deterioration experiment are as follows:

Manure under our conditions does not lose in weight as rapidly as in more humid regions. The sheep manure lost 32.5 percent in weight in about 15 months, and 56.7 percent in a little over two years.

About half (48.6 percent) of the total nitrogen was lost during the first 15 months, and 68 percent was lost in two years. The total nitrogen sustains the heaviest loss of any of the elements of plant fertility in semi-arid climates.

The phosphoric acid decreased 42 percent in 15 months, and 59 percent in two years. The loss in weight seems to fairly represent the loss of phosphoric acid.

The great difference between manures in semi-arid and humid climates is expressed in the potash. Practically all who have conducted experiments along this line mention potash as the most easily lost of the three elements of plant food, and that it is lost by leaching. Our manures retain the potash, probably due to the light rainfall. In the first 15 months no loss was found. The second year an absolute loss of 35 percent of the potash occurred. That the potash in fresh manure is soluble was demonstrated by experiment. Air-dried sheep manure lost 17.8 percent when washed with water, which represents a loss of 43.7 percent of the potash, 22.6 percent of the phosphoric acid, and 39.0 percent of the nitrogen.

From the 23 analyses of sheep manure, we learn that they contain on the average 13 percent less moisture than an average of sheep manures in moist climates.

The phosphoric acid remains at about one percent of the dry matter irrespective of the age of the manure.

The potash in this series of samples increases from an average of 4.4 percent in the fresh manures to 6.3 percent in the one-year-old samples, and remains at about this figure for several years, which corroborates the summarized statement in regard to the potash in the deterioration experiment.

There is a large loss of total nitrogen during the first two years. Almost the whole of this loss is due to a loss of free ammonia, which is produced in large amounts by the action of uro-bacteria.

The moisture in the manure plays a large part in retaining the free ammonia.

Nitrogen as nitrates varied widely. There was none in the fresh manures even after keeping the air-dried samples in the laboratory several years. As much as 27 percent of the total nitrogen was found present as nitrates in one sample. There was, however, no uniformity in the results, i. e., some of the older manures carried large amounts of nitrates while other samples of the same age carried almost none.

The carbon and hydrogen in manures are present in practically constant quantities, the age seemingly having nothing to do with the amount. This was true in both the cattle and sheep manures and in both the soluble ash is nearly a constant quantity.

Taking the results of all the tables as a whole, one is impressed by the sameness of the different determinations; especially is this true of the soluble ash, the potash, the phosphoric acid, the carbon and hydrogen. It is not true, of course, of the insoluble ash which increases decidedly with age, nor of the free ammonia and nitrogen which decrease with age. This sameness in the results means that, under our conditions at least, the manure is broken down by bacterial life at about the same rate that leaching carries away the soluble salts.

Bulletin 169 November, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

SOME INSECTS AND MITES ATTACKING THE PEACH IN COLORADO

By GEORGE P. WELDON

TWO PLANT LICE OF THE PEACH

By C. P. GILLETTE and GEORGE P. WELDON

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PLATE 1—FIG. 1

FIG. 2

FIG. 3

PLATE 1—FIGURE 1, Peach leaves curled by green peach louse. FIGURE 2, Black peach aphis on twig early in spring. FIGURE 3 shows one green peach leaf and three faded ones caused by attack of brown mites.

SOME INSECTS AND MITES ATTACKING THE PEACH IN COLORADO

By GEORGE P. WELDON

The peach industry in the western slope region of Colorado is one of much importance, and the need for literature treating of a few insect pests and mites that the peach grower must reckon with, seems to be great enough to justify the publication of this bulletin.

The novice in the business of growing peaches in Colorado very often begins with a mistaken notion that peach trees require no spraying. That notion has probably grown out of the fact that in the early history of orcharding in the State, spraying for the control of insect pests was confined almost entirely to apples. While the spraying of peach trees may not be necessary every season, there are times when certain sprays are necessary in order that destructive pests may be controlled. One who hopes to make a success growing high grade fruit must resort to spraying whenever the prevalence of some insect pest demands it. It would not be wise to lay down set rules for the spraying of peaches, for there are too many factors that may bring about a marked increase or decrease in the numbers of certain pests occurring from season to season. For example, last spring a very severe infestation of the common green peach aphis in the peach growing sections of Colorado, made it necessary that stringent methods of spraying be adopted. The previous spring the ocurrence of this pest was very general, but it was not abundant enough in most orchards so that it was necessary to spray for its control. Often a dormant spray of lime and sulphur, or soluble oil is beneficial in orchards where certain pests may be spending the winter. Too much, however, should not be expected of dormant sprays, and while there are insects that they may control very effectively, there are others that will be controlled but partially or not at all. Very often the orchardist who uses a lime and sulfur spray, seems to lose sight of this fact, and because the spray does not meet with his expectations in controlling some certain pest, he condemns it for all of them. As a matter of fact he probably was paid for its use in the destruction of some other pest.

THE PEACH TWIG-BORER (*Anarsia lineatella* Zell)

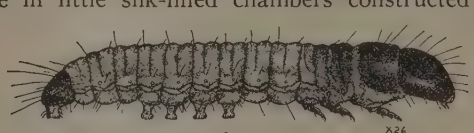
One of the most common enemies of the peach in the United States, is the twig-borer, or "bud worm" as it is sometimes called. Its occurrence has been reported from most of the peach growing states of the Union, both in the East and West.

In Colorado it has been known for a number of years, and while it is not a seriously injurious pest every season, there are seasons when it becomes exceedingly destructive, and is responsible for a great financial loss to those peach growers who do not adopt proper methods of control.

The adult of the twig-borer is a tiny, dark gray moth. It is an Old World species, supposed to have come to us with the peach from Western Asia, and has been known in the United States since 1860.

Kind of Trees Affected.—The twig-borer is principally an enemy of the peach, and usually we hear of it in connection with its damage to this fruit. It may be found, however, on all stone-fruit trees, but shows a decided preference for the peach. In Bulletin 80, of the United States Department of Agriculture, Dr. Marlatt mentions the pear among its list of food plants. The writer has never noted the attack of this insect upon other than stone-fruit trees. Its occurrence on the pear or other pome fruits is probably rare, and might be compared to the occurrence of the codling moth, which is almost exclusively an enemy of the pome fruits, in plums, peaches, or other stone-fruits. While cases of codling moth infesting stone-fruits in any numbers are rare, they were found the past season, so plentiful in Burbank plums of a certain orchard, that they were really doing considerable damage. The twig-borer, during a season of abundance, might occasionally modify its habits to the extent of an occasional attack upon pome fruits, as the codling moth in a season of abundance may modify its habits and occasionally attack stone-fruits.

The Larvae and Their Injury.—The larvae, as is shown in Fig. 1, hibernate in little silk-lined chambers constructed within the



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bark and very close to its surface. Mr. Warren T. Clarke, in his bulletin, *states that "in the majority of cases they are found just beneath a thin layer of the greener cells, just below the brown bark, while the greater part of the burrow is in the yellowish portion of the cambium." He also states, in connection with the winter burrow within the bark, that: "The postion generally chosen on the tree for the purpose is the crotch formed where the new wood joins that of the previous year, though older crotches are occasionally selected." In Colorado I have found them almost entirely in the older crotches and always, when found there, they have been in the brown portion of the bark, just as close to its surface as the hibernacula could be constructed. Occasionally the hibernating cells containing larvae, have been found underneath buds on the new growth of peach trees. Their occurrence in this location does not seem to be at all general.

*Bull. 144, Calif. Exp. Sta.

While hibernating the larvae vary somewhat in size, but are all very small, and their detection is somewhat difficult, except when very close observations are made. The presence of the larvae themselves during the hibernating period, could scarcely be detected were it not for the fact that they construct, at the entrance to their burrows, tiny silken tubes covered on the outside with bits of bark, which were chewed off by the larvae while excavating the hibernacula. These little tubes are shown in the crotch of a tree in Fig. 3, and again one is shown at the entrance to a burrow containing larvae in Fig. 2. The larval cell is also lined with silk, the silken tube being merely a continuation of this cell lining. Throughout the winter months the hibernating larvae remain inactive within this

cell. Apparently no feeding is done after the time that they construct the cells until they leave in the spring, consequently no growth takes place during that time. A hibernating larva, magnified 26 diameters, is shown in Fig. 1. These larvae are exceedingly well protected in their hibernacula, and Mr. Warren T. Clarke's experiments in California show that they are almost impenetrable to even an oil spray during the winter season.

In the spring of the year, about the time the peach trees bloom, the larvae leave their winter quarters and eat into the tips of the twigs, either beginning their work at the extremities or a short distance below, sometimes hollowing them out for usually a distance of less than an inch from where the twig was entered, leaving a mere shell or hollow cylinder of the portion in which they have fed. Again they may merely gouge out the tip of a twig on one side, entering in as far as the pith and then leaving for some other twig. Thus they go from twig to twig, feeding first in one and then in another, until often the tips of a great many branches will be killed back, thereby

checking their growth and more or less injuring the tree. The detection of their work is no difficult matter a short time after they begin feeding, for the leaves of affected twigs soon wilt, as in Fig. 3, and later dry up from the injury done to them.

The injury the first brood larvae do to twigs, while sometimes alarming, is not usually to be compared with the injury to the fruit from the second and third broods. Often this injury to the fruit is extensive enough to render great quantities of it unmarketable, and we have a condition of peaches comparable to that of apples as a result of codling moth attack. The larvae usually enter the fruit from the stem end and may feed entirely within the flesh, but very often they eat their way into the pits. Affected peaches may be detected by an issuance of sap mixed with little pellets from the fruit which have been chewed up by the larvae. This sap hardens on the outside and peaches so effected, are often termed "gummy peaches."

The Pupal Stage.—This stage of the insect is said to last from 6 to 12 days, the first brood remaining pupae for the longest time. This period is passed by the first brood pupae, according to Mr. Clarke, principally in curls of bark on the trunks of trees. They may, however, be found in other places, such as between two peaches which come in contact with each other, under rubbish on the ground, etc. The cocoon which they make is a very flimsy one; in fact, so much so that in reality it should not be termed a cocoon. A few strands of silk are spun by the larvae, and to these strands the pupae is attached by means of hooks at the tip of the abdomen. The second and third brood pupae more often pupate in the suture at stem end of peaches than underneath the bark, and the semblance to cocoons is even less than in the case of the first brood.

The Moth.—The twig-borer moth is a tiny, gray insect, about ¼ inch in length and having a wing expanse of about ½ inch. It is quite a beautiful little moth with its dark gray, fringed wings. They are very seldom seen in the orchards by the fruit growers, because of their small size, their close resemblance to projections of the bark and their habit of resting perfectly still during the day time on the trees.

The Egg.—Eggs of this insect were first found by Dr. Marlatt, who kept the moths in confinement and found that they were deposited above the bases of the petioles of the leaves. Mr. Clarke, in California, found the eggs of the first brood in the orchard, in the same location as described by Marlatt. He found, however, that the eggs of the second generation of moths, were laid not on the twigs, but on the fruit and in the edge of the stem end depression; the eggs of the third generation were found in cracks of the bark, or exposed on its surface, just above the crotches formed by the new wood, and on the old wood.

The eggs are pearly white, changing to a deep yellow before hatching. They are quite conspicuous, being about 2/5 of a millimeter (1/60 of an inch) in length by 1/5 mm. (1/120 inch) in breadth.

These observations of the egg and egg-laying habits of the insect, made in California by Mr. Clarke, are very interesting, as they are the first recorded from studies made under the natural conditions of the orchard.

Experiments for Control of the Twig-borer.—The experiments testing different insecticides for the control of this pest, were all conducted in the spring of 1910, and were combined with the green-peach aphis experiments recorded in this bulletin, with the discussion of the latter pest.

The comparative scarcity of twig-borer the past season made it difficult to secure much reliable data from the experiments. Table I was compiled from data gathered in the W. C. Strain orchard at Clifton, and Table III gives general results of all the experiments in both the Strain and Paxson orchards.

TABLE I.

Results attained with different insecticides in controlling the peach twig-borer, in the W. C. Strian orchard at Clifton, Colo.

Insecticide Used	Strength Used	Date Sprayed	Date Examined	Wilted Tips	Trees Examined
Black Leaf	1–30	March 7	April 26	5	3
Black Leaf	1–40	"	"	6	3
Black Leaf	1–50	"	"	3	3
Black Leaf	1–70	"	"	0	1
Black Leaf "40"	1–600	"	"	0	2
Black Leaf "40"	1 800	"	"	7	4
Black Leaf "40"	1–1000	"	"	6	4
Lime and Sulfur	1–10	"	"	0	12
Lime and Sulfur	1–11	"	"	0	
Soluble Oil	1–20	"	"	4	2
Unsprayed				16	4

While it is not thought that this year's experimental work with twig-borer, would justify the drawing of many conclusions, there were at least some helpful hints gathered in regard to its control. It may be seen from Table I that "Rex" Lime and Sulfur gave perfect results. More trees were sprayed with the "Rex" mixture 1-10 and 1-11, than with any other insecticide, yet in a very careful examination of 12 trees by Mr. Strain and myself, we failed to detect the presence of a single wilted twig because of the work of the borer. On 4 check trees in the same block 16 wilted tips were counted, and on 22 trees sprayed with tobacco preparations and soluble oil, 31 wilted tips in all were counted. One tree sprayed with Black Leaf

1-70 was free from wilted tips, and also 2 trees sprayed with Black Leaf "40" 1-600. The fact that the higher strengths of Black Leaf did no appreciable good, would indicate that it was simply a matter of chance that the one tree sprayed with the weaker strength, indicated good results. Black Leaf "40" 1-600 apparently gave good results, however, because of only two trees having been treated, and because of the scarcity of the twig-borers in the orchard, it would not be wise to draw any definite conclusions without further experiments. The number of trees treated with lime and sulfur and their total freedom from borers, seemed great enough, when compared with the small number of check trees, and other sprayed trees with quite a number of borers, to justify the conclusion that "Rex" lime and sulfur is a perfectly effective spring remedy for this pest. For some unknown reason home prepared lime and sulfur used at the same time as the "Rex" spray, but in another orchard, apparently did little good.

Mr. W. T. Clarke, in Bulletin 144, of the California Experiment Station, at Berkeley, gives some interesting data in regard to sprays applied at different times of the winter and spring, for the control of twig-borer. He found that during the winter season the little larvae, in their hibernating cells, could not be killed either with kerosene emulsion or lime and sulfur. He discovered, however, that the larvae become active in these cells for some time in the spring before emerging, and that during this period of activity the cells are rendered more or less permeable to a spray, and then the larvae can be successfully combated with a contact insecticide. In regard to the effective use of a spring spray of lime and sulfur, Mr. Clarke says:

"The lime-salt-and-sulfur-sprayed trees, when the spraying had been done in the early spring, showed the most satisfactory results of any at the time of examination. On the various station orchards, comprising over 12,000 peach trees, the average number of bud-worms was about one to every ten trees, and this average was maintained on many orchards in the district. Indeed, it was a difficult matter to find the worms in these orchards, and it was only by the closest scrutiny of the trees that they could be located in them. The general condition of these trees was excellent, and a marked absence of 'curl-leaf' was noted.

"An examination of the trees in orchard No. 1, that had been sprayed with the lime salt and sulful early in February, showed that the attack of bud-worms was severe. On many of the trees from which we cut the worms we found from 5 to 9 to the tree. The general condition of the trees was good and a very small amount of 'curl-leaf' was present."

From this season's experiment at Clifton, from the experience

of the many Colorado orchardists who have used lime and sulfur for the control of this pest, and from the apparent success of this spray in California, we feel justified in recommending it for use in the sections of Colorado where there is injury from twig-borer.

While arsenate of lead was a total disappointment in this season's tests, it has previously been used with good success and is, no doubt, effective when applied at the proper time. E. P. Taylor, in his annual report of the Western Slope Fruit Investigations for 1906, gives some very satisfactory results from the use of 5 pounds of arsenate of lead to 50 gallons of water, applied on April 14, at which time the majority of the blossom buds showed their pink tips. Commenting upon the results of his experimental work, he wrote: "It may be said that arsenate of lead, applied in the spring at the time the buds of the peach are beginning to open, will control the peach twig-borer as effectively and cheaply as the lime and sulfur wash, up to this time the most universally used."

THE PEACH TREE-BORER *(Sanninoidea exitiosa)*

Colorado peach growers are fortunate in that they do not, as a rule, have the crown-borer of the peach to fight. In many of the peach-growing sections of the United States, this is one of the worst pests preying upon the trees. Unlike the twig-borer, which feeds upon the tender twigs and fruit, this species feeds just beneath the bark at the crown of trees, often girdling them. The adult insect is a moth which, at a glance, more closely resembles some kind of a bee or wasp, than a moth. The eggs of this moth are deposited on the trunks of peach trees, and the little worm-like larvae hatching from them, eat their way beneath the bark and there feed until full grown.

The work of the insect may be detected by masses of gum in which are mixed pellets of wood or borings which the larva chews to pieces as it feeds. These gum masses usually occur at, or just below the ground line. Their presence aids in the fight against this pest, as the burrows in which the larvae feed can always be found beneath. By using the point of a knife or a piece of wire, this burrow may be followed and the larva located and killed. No better method for combating the peach tree-borer has ever been devised than worming, as the above process is called, with a knife or some other implement that can be inserted into the burrow. Worming should be done both in the fall and spring. While the larvae often do not attain a sufficient size in the fall to be readily detected, a great many of them can be killed before they get in very far, thus preventing the damage that they might do before they could be detected in the spring.

Various other methods of control have been tried, such as wrapping the trunks with tar paper to keep the moths from deposit-

ing their eggs, applying repellants for the same purpose, and mounding the soil up above the crown of the tree. This last named method is valuable in that where it is used the larvae may be induced to enter the trunk of a tree some distance above the surface of the ground, then when the mound is removed the worms are high on the trunk, where they can be much more easily destroyed than if they were lower down.

SCALE INSECTS.

It is very fortunate that none of the scale insects have as yet been found abundantly on peach trees in Colorado. The San Jose scale has been seen on a very few trees, but not plentiful enough to do any serious injury. This pest seems to confine its attacks more to the apple in the few orchards where it has been found.

In one section of the Grand Valley a scale insect closely allied to the dreaded San Jose is found. Samples of this scale were sent to Prof. T. D. A. Cockerell, Entomologist in the State University at Boulder, who kindly determined it for me as the putnam scale. Only in rare cases has this insect been found doing serious injury.

There are other scales of minor importance that are sometimes found on peach trees; all of these insects may be successfully combated with an early spring spray of lime and sulfur, or soluble oil. If Rex lime and sulfur is used it should be diluted by using 1 part of the Rex solution to 10 parts of water. A good home-made lime and sulfur is as effective as the Rex, and should be made with 20 pounds of lime and 15 pounds of sulfur to 50 gallons of water. Soluble oil is ordinarily used at a strength of one part of the oil to from 15 to 20 parts of water.

While spring spraying for the control of these scale insects is probably more advantageous than a spray at any other time, good work can also be done with a fall application. Very often orchardists would rather spray in the fall because there is more time to do so than in the spring.

THE BROWN MITE (*Bryobia pratensis* Garman)

In Bulletin 152, of this Experiment Station, an account was given of the life habits and injuries from this species of mite, and also the red spider. As this bulletin is still available it will not be necessary to again give a detailed account of these two pests.

This mite passes the winter almost entirely in the egg stage. These eggs are tiny, red spherical-shaped, glassy objects, usually deposited in or near crotches of the branches. Hatching takes place in the spring. At first the young mites are red in color and have only six eggs. Upon feeding for a short time moulting takes place, after which the mite is olive green, or brown in color, and has eight legs more or less tinged with red. It feeds principally upon the leaves, occasionally attacking the fruit, and may be detected by the

faded out, pallid appearance of the foliage, dotted here and there with little black specks of excreta. Plate I Fig. 3 shows two peach leaves which have been attacked and two which are normal from the same tree, and gives a good idea of their appearance after this pest has been feeding upon them.

Control Measures.—Experiments recorded in Bulletin 152 show that tobacco preparations are of little value in controlling this mite; that they will kill the mites, but not the eggs. As the latter are almost always present on a tree where the mites are feeding, such sprays can only be effective when repeated applications are made. The sulfur spray was again tested this season, this time at Palisade, Colorado. Some badly infested pear trees were treated, using 10 pounds of sulfur to 50 gallons of water. Results of this test were perfect, and a week after the trees had been sprayed it was hard to find a living mite on them.

An interesting point in connection with the sulfur treatment for brown mite is: The adult mites are not immediately affected by the spray, but those newly hatched die shortly after the application. An examination of a tree the day after spraying with sulfur is usually disappointing, for the adult mites may be alive and abundant. In all the tests made a very few newly hatched, six-legged mites have been found, 24 hours after spraying, and in a week's time neither adult nor newly hatched mites can be found. The sulfur adhering to the bark and leaves, undoubtedly kills the young mites as they hatch from the eggs. Whether the older ones are killed by the sulfur or simply die a natural death is a point that has not been determined definitely. As there are probably only three broods of this mite, and they are quite long lived, it would seem that the sulfur really kills the adults, but that it takes some days to do so. The important fact remains that the young mites never develop after the sulfur treatment, whether hatched or in the egg stage at the time of treatment, and that the adult mites are either killed by the sulfur or die a natural death within 7 or 8 days after treatment, thus ridding infested trees of the pest.

Lime and Sulfur an Efficient Remedy.—In Bulletin 152 the following statement was made: "Trees may be treated while dormant with lime and sulfur. This spray has no effect upon the eggs, but probably kills the young mites as they hatch." The fact that the lime and sulfur kills the young mites as they hatch was definitely established last spring at Palisade, Colorado.

Three adjoining peach orchards, each containing a great many brown mite eggs—two of them sprayed with Rex lime and sulfur 1-10, and one not sprayed—were chosen as observation places to determine this point. The eggs were found hatching in all three orchards at the same time; in the orchards which were sprayed a great

many of the tiny, red mites could be found where they had died on the limbs very soon after hatching. In no case were any found alive, except a few immediately hatched from the eggs. In the unsprayed orchard all the mites seemed to live and the trees were soon covered with them. Throughout the season the sprayed orchards were almost entirely free from mites, while the unsprayed one, located between the other two, had quite a serious infestation.

As a result of the extensive use of a lime and sulfur spray in the Palisade section the past season, the brown mite was practically exterminated, except in a few orchards where such a spray was not used.

THE RED SPIDER *(Tetranychus bimaculatus)*

This mite differs from the preceding one in its wintering habits; instead of living over in the egg stage, as the brown mite does. this species hibernates in the soil as an adult, close to trees upon which it has been feeding, or underneath rubbish of any kind. On the 7th of November, this season, they were found plentifully, under burlap bands that had been applied to trees for the purpose of trapping the codling moth larvae. Hibernation begins before the cold weather sets in; the first downward migration of mites to the soil was noticed at Grand Junction, this season, on July 26. While a few of them may work on trees until late in the fall, their damage is usually over by the 15th of August.

Eggs are laid in the spring by mites that have lived through the winter. These eggs are pearly white, and may be seen as tiny specks on the under surface of the leaves.

When first hatched from the egg this mite, like the species previously treated, has only six legs, the fourth pair developing with the first moult. They are somewhat smaller than the brown mite, usually green in color while feeding upon the foliage of trees, with minute black dots on the dorsum of the abdomen. When feeding ceases in the fall, and they begin their downward migrations to the soil, they become an orange, or red color. During my observations of this species of mite, for the past three years, a red one has never been seen on fruit trees until feeding ceases in late summer. In greenhouses this same species is very often red in color. Unlike the brown mite, the red spider has the power of spinning a web, and may easily be detected, when prevalent, by the presence of these webs on the foliage, or branches of infested trees. The appearance of injured peach foliage is not unlike the appearance of that injured by the brown mite, but is more inclined to turn yellow in patches.

Control Measures.—Sulfur is very successful in treating this mite also, whether dusted upon or applied as a liquid spray to infested trees. When applied in water, by means of a spray, sulfur should be very finely screened, and mixed with the water by using

a small amount of soap. Without the soap the sulfur will remain on the surface of the water, while with the soap it will sink to the bottom of the spray tank, and a good agitator will keep it mixed.

Lime and sulfur has not proven a successful treatment for red spider, and cannot be depended upon to do effective work when used as a dormant spray.

The use of tobacco preparations, as with the brown mite, result in little good.

TWO PLANT LICE OF THE PEACH

By C. P. GILLETTE and GEORGE P. WELDON

THE GREEN PEACH APHIS (*Myzus persicae* Sulz)

This is the common green peach louse so prevalent early in the season curling the leaves and often attacking the blossoms and forming peaches in a most destructive manner.

This insect was quite fully treated and figured in its natural colors in Bulletin 133 of this Station, by Gillette and Taylor. Copies of this bulletin are still available for those requesting it.

How the Winter Is Spent.—The eggs of this species of plant louse are deposited on peach trees, (occasionally on other stone fruit trees), in the fall, where they remain unhatched until early spring. Their detection is not as easy as that of the common green apple aphis egg, but is not extremely difficult when one knows where to look for them. Last fall the eggs were deposited in such large numbers that they could be easily found in a great many orchards. In some cases the buds of peach twigs were dotted black with them. Usually these eggs are deposited on, or very close to a bud, (See Fig. 4), and very often just as deep in wrinkles or depressions as possible, and unless they are plentiful, it may require sharp eyes to detect them. When first deposited, the eggs are light green in color, turning black after exposure to the air. They are much smaller than the eggs of the common green apple aphis, which nearly every orchardist has seen, but are quite similar in shape, color and general appearance. This pest may live over winter on vegetation that remains green throughout the winter season, so there would be a possibility of trees becoming infested at least late in the season from other sources, even though the eggs were all killed by an insecticide, or failed to hatch because of unfavorable weather conditions or other causes.

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The eggs of this aphis hatch very early in the spring. E. F. Taylor reports having found them hatching at Grand Junction, Colorado, on the 16th day of February, 1907. The month of February that winter was unusually warm and the extremely early hatching of the eggs was due to that fact. However, hatching takes place when the buds have scarcely begun to swell, a fact which is not generally understood by the fruit grower, and one which is of very great importance in its relation to the control of the pest by means of a spray. The past spring, eggs were found hatching on the 7th of March at Clifton, Colorado, at which time the buds seemed perfectly dormant.

Spring Habits.—When first hatched from the eggs these aphids are dark green in color, and may be seen as tiny, dark specks crawling along the twigs, or more often, clinging to the buds. It is probable that they can exist for a number of days after hatching with little or no food. What feeding they do takes place on the buds or very tender bark into which their beaks are inserted, and from which a portion of the early flow of sap is extracted. Plant lice of the spring brood, which hatch from eggs that have remained on trees over winter, are known to the entomologist as stem-mothers. The full grown stem-mothers of this plant louse are of a pinkish or salmon color, and before there is a sign of a peach blossom in the spring, these stem-mothers have begun reproduction. Their progeny are born alive, eggs never being laid except in the fall, and then by an aphis which, though only a different form of the same species, might be taken by the orchardist for an entirely different kind of plant louse. The generation from the stem-mothers differ from the latter in that they are light green in color, with darker green, longitudinal markings on the dorsal surface of the abdomen, but are never pink like the stem-mothers. Just as soon as the buds on infested trees begin to unfold, the stem-mothers, with their progeny, are ready to enter within. At first they seem to prefer feeding in the blossoms, but after these fall, quite serious injury is often done by their feeding on the leaves. Probably the greatest injury to peaches resulting from their attack, consists in the dropping of the small fruit which has become devitalized from the loss of sap until it can make no growth, hence shrivels and falls to the ground. The injury to the peach is practically all done while it is yet in the husk or calyx tube. After the peach has cast off this calyx tube it is not likely to be molested further by the aphids, and unless it has been too much weakened before this time, the probabilities are that it will not drop as the result of aphis attack.

Summer Habits.—Fortunately this pest cannot, or does not, spend its entire existence upon the peach or other trees, but leaves them for more succulent vegetation. Shortly after the peaches are

formed, winged lice begin to appear in the colonies; these fly away to other food plants, and by the last of June very few can be found on peach trees. This is indeed a blessing to the peach grower, for should this pest continue its ravages throughout the summer on the peach, it would require great effort and expense to control it. As it is, trees often suffer a great loss of foliage, and if it were not for the wonderful power of the peach tree to recover after this injury, the result of the aphis attack would be more disastrous.

Gillette and Taylor, in Bulletin 133, of the Colorado Experiment Station, gave a list of 53 plants growing in the greenhouse, which were found to be infested with this aphis, and 25 plants growing out of doors, the out-of-door plants comprising most of the common garden vegetables and weeds. The variety of plants upon which this louse feeds during the summer time is so great that it is probable that it will seldom be plentiful enough on any one kind to do serious injury. While on the summer food plants, this aphis is usually light yellow in color, and without the green stripes so characteristic of it while feeding on the peach.

Fall Habits.—The last winged generation of lice appearing in the fall are known as fall migrants, because of the fact that they leave the vegetation upon which the summer has been spent and migrate to peach trees. These fall migrants do not deposit eggs, but give birth to the true sexual forms, males and females. The females are pink in color, somewhat similar to the stem-mothers which were on the trees in the spring, but smaller. After feeding for a time and becoming mature they deposit the eggs previously described.

Spraying Experiments.—Because of the abundance of green peach aphis eggs last winter, a number of different tests were made in the spring, with various insecticides, in order to determine their value as egg destroyers. The spraying was delayed a little too long, however, and on the 7th of March, when the first applications were made in the W. C. Strain orchard at Clifton, many of the eggs were found to be hatching, and there was no trouble in finding the little green lice here and there on the twigs. A great many of the eggs were not hatched at that time, hence the various sprays were tested as destroyers of both the eggs and the young lice. The block of trees sprayed in the Strain orchard, was only three years old, but contained both the eggs of green peach aphis and the hibernating larvae of the twig-borer in abundance. The small size of the trees made very thorough spraying possible. The work was done with a Morrill and Morley barrel pump, so it was not possible to make the applications with a high pressure. Thoroughness was depended upon to compensate for the deficiency in pressure. Tests were made in this orchard with Rex lime and sulfur, two strengths, namely: 1 gallon

of the "Rex" to 10, and 1 to 11 gallons of water; Black Leaf tobacco extract, four strengths, namely: 1 gallon to 30, 1 gallon to 40, 1 gallon to 50, and 1 gallon to 70 gallons of water; Black Leaf "40," three strengths, namely: 1 gallon to 600, 1 gallon to 800, and 1 gallon to 1,000 gallons of water; soluble oil, 1 strength, namely: 1 gallon to 20 gallons of water. Thirty-eight trees in all were sprayed in this test, and 5 were left without any treatment, for checks.

On the 8th of March, 21 trees were sprayed in Mr. M. Paxson's orchard at Clifton. These trees were five years of age, and fully as many eggs of the aphis, and larvae of the twig-borer were found on them as in the Strain orchard. The following insecticides were used on this date: Nico-fume at two strengths, namely, 1 gallon of Nico-fume to 600, and 1 gallon to 800 gallons of water. Kerosene emulsion was applied at one strength only, namely, a 15 per cent. oil emulsion prepared by using a common laundry soap. Black Leaf was applied at one strength, namely, 1 gallon to 55 gallons of water. Home prepared lime and sulfur was applied at one strength, namely, 15 pounds of lime and 15 pounds of sulfur to 50 gallons of water. This lime and sulfur was made in the ordinary way, and was boiled for one hour, so that a first class lime and sulfur spray was prepared.

On March 28th the peach buds were just showing their pink tips, and several sprays were again applied. At this time three of the tests were made with a mixed spray of arsenate of lead and one of the tobacco preparations, the arsenate of lead being used for the twig-borer, and the tobacco preparation with which it was mixed, for the aphis. The following insecticides were applied at this time to about 150 trees: Rex lime and sulfur, 1 gallon to 10 gallons of water; Black Leaf, 1 gallon to 50 gallons of water; Black Leaf, 1 gallon to 70 gallons of water, combined with arsenate of lead 3 pounds to 100 gallons of water; Black Leaf "40," 1 gallon to 800 gallons of water; Black Leaf "40," 1 gallon to 1,000 gallons of water, combined with arsenate of lead 6 pounds to 100 gallons of water; Black Leaf "40," 1 gallon to 900 gallons of water, combined with arsenate of lead 10 pounds to 100 gallons of water.

Results of Experiments.—Table II gives the results of the first examination made on March 15, of trees sprayed in the Strain orchard. It may be seen from this table that all insecticides applied on March 7th resulted in effective control, at all strengths. Subsequent examinations were made on March 24th, April 26th, and May 11th, each one indicating practically the same results. It would seem from this experiment, that just as the eggs of this aphis are beginning to hatch is a favorable time to spray for its control. Lime and sulfur proved to be a perfect spray at this time. Appar-

ently, it gave a little better final results than anything else used. Table III gives a summary of results in both the Strain and Paxson orchards. It may be seen from this table that, with the exception of Nico-fume, all the tobacco sprays of both early and late applications resulted in much good, but that lime and sulfur applied on the latest date of spraying did not prove beneficial. This application of lime and sulful was made at a time when some of the first lime and sulfur spraying was being done in the Valley, but earlier than much of it. The experience of most of the orchardists was: that the lime and sulfur did no good applied late for green peach aphis, which tallies with our experience. This season's experiments indicate that the most important thing in connection with the control of this aphis by the use of lime and sulfur, is to get it on early; just as the eggs were beginning to hatch was found to be a splendid time. If spraying is delayed until the aphis becomes full grown, some other spray besides the lime and sulfur should be used. This spray will not kill the mature stem-mothers unless applied in excessive quantities.

The tobacco sprays are much better to use when mature lice can be found. But these preparations are also more effectual at the time when the eggs are hatching. A great amount of material is required in order to be thoro enough to kill most of the lice after they are fully grown.

The average orchardist would probably have a hard time to detect the little lice when they are first hatched, but the importance of spraying at this time should be sufficient reason for him to learn to find them. If this is not possible it would be reasonably safe to say that the lice may be found hatching after the first few days of warm spring weather in February or March, in the vicinity of Grand Junction, and that a spray at such a time would be successful. A hand lens, costing 25 to 50 cents, is of great service in finding the lice.

On March 25th some large Triumph peach trees were sprayed on the C. H. Dilley place at Clifton. These trees had been sprayed a few days previously with lime and sulfur, but apparently with no success in killing the aphis, which at this time were clinging to the partially open blossoms waiting for a chance to get within. Part of these trees were treated with Black Leaf, 1 gallon to 70 gallons of water, and the rest with Black Leaf "40," 1 gallon to 800 gallons of water. By exceedingly careful and thoro spraying, entailing the use of at least ten gallons of spray to a tree, it was found that practically all the lice could be killed. The Elberta trees in this orchard did not have so many of the aphids on them, and the manager of the place decided that they did not need to be sprayed. On May 11th an examination of these trees showed the Elbertas to be badly in-

fested, and the Triumphs, which we had sprayed, were exceedingly clean. The difficulty experienced in spraying trees so late in the season, lies in the fact that the leaves always tend to curl and provide such protection for the lice, that only the most thoro work can result in much good.

THORONESS NECESSARY TO SUCCESSFUL SPRAYING.

No matter when the spraying may be done for the control of this insect, success cannot be attained unless a very thoro application of the insecticide is made. In fact, this is a general rule that will hold good in spraying for the control of all insect pests. While this point is always emphasized by entomologists, our experience with orchardists has been that many do not have a proper conception of what thoro spraying means. This may be due in part to the failure to appreciate the fact that insects multiply tremendously in a short time, and unless a spray kills practically all of a pest, such as the one in question, a few days or weeks may see them as plentiful as they were before the spray was applied. Spraying investigations in the orchard indicate, also, that much of the trouble is due to the expense of a proper treatment. Most of the insecticides used are very high priced, and the orchardist does not feel that he can go to the expense necessary to thoroly treat his trees. He very often fails to realize that work such as this, half done, is really work wasted, to say nothing of the expense.

It is safe to say that spraying for the control of the green peach aphis can only be successful when very great care is used to thoroly drench every portion of infested trees.

CONCLUSIONS.

1. Lime and sulfur, both Rex and home prepared, Black Leaf extract, Black Leaf "40," and soluble oil, may be effectively used for the control of the green peach aphis when applied in the early spring just as the eggs are hatching.

2. A lime and sulfur spray is not effective when applied two weeks or more, after the eggs are hatched, for at this time the stem-mothers are mature, or nearly so, and are able to resist the action of this insecticide.

3. Good tobacco preparations may be used with success any time after the aphids hatch, but it is more difficult to succeed late in the spring, because it is then more difficult to get the spray on all the lice, on account of the protection of the leaves.

4. The best time to spray for this insect is in the early spring when the eggs are hatching.

Table II, giving results attained in killing eggs and newly hatched lice of the green peach aphis on small trees in the W. C. Strain orchard at Clifton:

TABLE II.

Insecticide Used	Strength of Insecticide	Date of Spraying	Date of Examination	No. of Aphids on 6 Twigs From 2 Trees
Black Leaf	1-30	March 7	March 15	2
Black Leaf	1-40	"	"	2
Black Leaf	1-50	"	"	1
Black Leaf	1-70	"	"	1
Black Leaf "40"	1-600	"	"	0
Black Leaf "40"	1-800	"	"	6
Black Leaf "40"	1-1000	"	"	7
Rex Lime and Sulfur	1-10	"	"	1
Rex Lime and Sulfur	1-11	"	"	2
Soluble Oil	1-20	"	"	0
Check				93

TABLE III

Insecticide Used	Strength	Date of Spraying	General Results in Killing Aphis		General Results in Killing Twig-Borer	
			Early Spray	Late Spray	Early Spray	Late Spray
Black Leaf	1-30	March 7	Good	-----	Unsatisfactory	------
Black Leaf	1-40	March 7	Good	-----	"	------
Black Leaf	1-50	March 7 and 28	Good	Good	"	Unsatisfactory
Black Leaf	1-70	March 7 and 28	Good	Good	Apparently good but not enough trees	"
Black Leaf "40"	1-600	March 7	Good	----	Good	------
Black Leaf "40"	1-800	March 7 and 28	Good	Good	Unsatisfactory	Unsatisfactory
Black Leaf "40"	1-1000	March 7	Good	----	"	------
Nico-Fume	1-600	March 7	Poor	----	"	------
Nico-Fume	1-800	March 7	Poor	----	"	------
Soluble Oil	1-20	March 7	Good	----	"	------
Ker. Emul	15% oil	March 7	Poor	----	"	------
Rex Lime & Sulfur	1-10	March 7 and 28	Good	Unsatisfactory	Good	Unsatisfactory
Rex Lime & Sulfur	1-11	March 7 and 28	Good	Unsatisfactory	Good	------
Lime and Sulfur	15-15-50	March 7	Good	----	Poor	Unsatisfactory
Black Leaf / Arsenate of Lead	1.70 / 3 lbs. to 100 gals	March 28	-----	Good	----	"
Lead Arsenate / Black Leaf "40"	10lb-100 / 1.900	March 28	-----	Good	----	"
Black Leaf "40" / Lead Arsenate	1-1000 / 6 lb-100	March 28	-----	Good	----	"

BLACK PEACH APHIS *(Aphis persicae niger)*

This enemy of the peach has never been of much economic importance in Colorado. It has been found from time to time, in the peach growing sections of the Western Slope, but apparently has not been able to continue for any length of time in orchards where it has been introduced. Notwithstanding the fact that up to the present time it has never made any headway in the orchards, it is well for the peach growers not to take any chances in orchards where it does appear, but to be prompt in making a very thoro application of Black Leaf, or some other good contact spray to infested trees.

The fact that this pest has the habit of feeding upon the roots as well as the twigs of peach trees, makes it one that is dreaded. Because of its ability to live below as well as above ground, it might become a serious pest if conditions should happen, at any time, to be favorable to its development.

Very often peach nursery stock coming from an infested nursery, is found to be badly infested with this aphis. When such trees are found they should be either carefully fumigated with hydrocyanic acid gas, or sprayed with a good contact insecticide such as Black Leaf, kerosene emulsion, or whale-oil soap. Plate I, Fig. 2 shows a section of a peach twig on which is a large number of these aphids. This twig was cut from a tree which had just been removed from a box shipped into the state from an outside nursery. There were so many aphids in the box that they found their way through the cracks and could actually be seen crawling on the outside in considerable numbers. The box bore a fumigation tag and the inspector, whose duty it was to look over all shipments of nursery trees into the county, rightly condemned all the trees in the box. The dark color of the adult lice and their habit of feeding on the tender bark rather than the leaves enables us to separate this louse readily from the foregoing species.

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

THINNING THE WINESAP

Winter and Frost Injuries of Fruit Trees

BY

R. S. HERRICK

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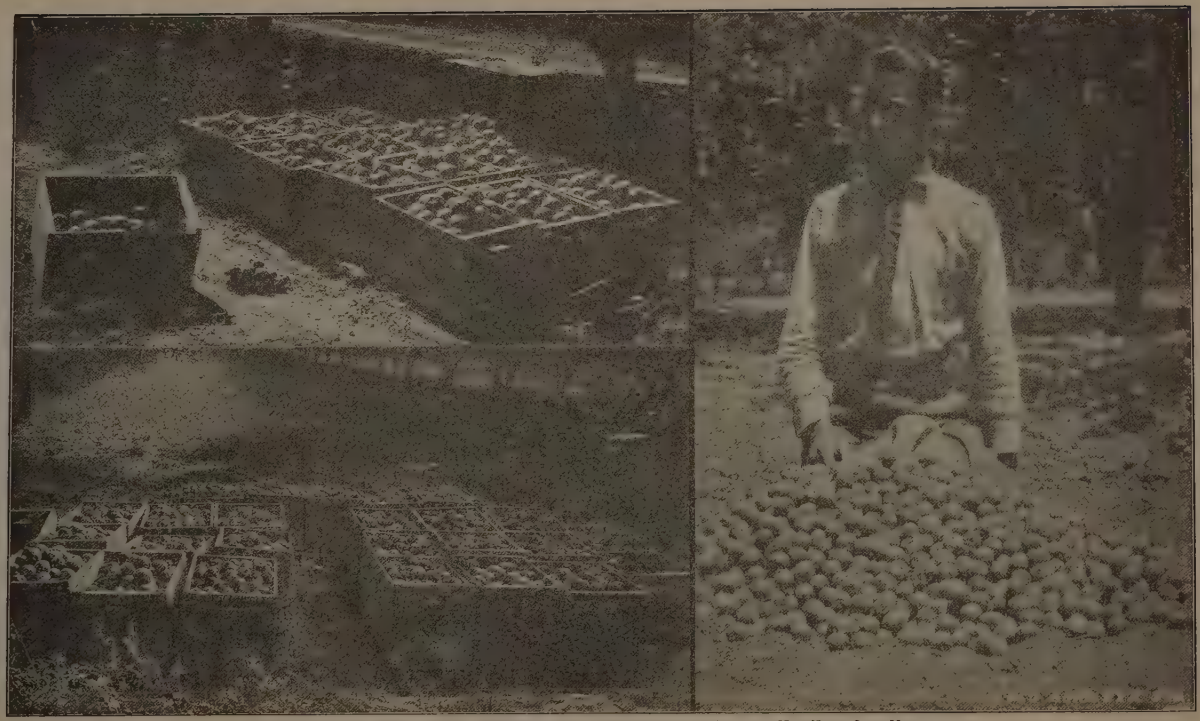

Fig. 1. (a) Apples from thinned tree No. 6. Note small pile of culls.
(b) Apples from unthinned tree No. 1. Five boxes of culls in rear.

THINNING OF THE WINESAP

By R. S. HERRICK

The Winesap apple, as a rule, does not attain sufficient size to meet the requirements for packing in the higher grades. This is especially true of heavily loaded old trees. It is not a "shy" bearer, but has a tendency to bear a heavy crop every year.

At a meeting of the representatives of the leading fruit growers' associations of the State, held at Grand Junction in February, 1910, rules were made and adopted for the grading of apples, which were as follows: "That the grade names be designated as 'Extra Fancy,' 'Extra Choice,' and 'Standard.' That the Extra Fancy grade is to include perfect apples, free from all blemishes, not less than 2½ inches in diameter for all varieties and of normal color, and layered throughout the box. That the Extra Choice is to include apples of not less than 2¼ inches in diameter and containing no worm holes and layered throughout the box. That the Standard grade be left to the discretion of the respective shippers." The Standard grade as packed by one of the leading fruit growers' associations of the State is as follows: "Pack in this grade all apples lacking in color or shape and pack nothing less than 2¼ inches in any variety. One small worm hole in side or end is allowed, but no more. If a worm hole is surrounded by a large discoloration, cull the apple. Leaf-rubbed or limb-scarred fruit, or fruit having two or three worm-stings is admissible."

It will be seen from the above rules that great care must be taken in the handling of the standard varieties of our apples, and in tending the orchard, to maintain a high grade of fruit. Among other things, careful attention must be given to the pruning, thinning, spraying, fertilizing, cultivating and irrigating. All of these are important factors in the management of an orchard; and, particularly with the Winesap, thinning should rank high among the requirements for best results. While every orchardist wishes to get the best possible yield for the season, at the same time it is better to have an average yield every season than a heavy crop one season and nothing the next. It is not claimed that thinning alone will attain this end, but there is no doubt that it will play an important part in doing so. If a tree will show a marked gain in value received from only one year's thinning, then it is important that the operation be continued.

In this bulletin the thinning of the Winesap will be discussed more fully than that of any other variety. A block of Winesaps and Jonathans was secured for a thinning experiment, in Mr. A. L. Robert's orchard at Paonia, Colorado. The Winesaps were about thirteen years old, set in rows running north and south, with the

trees 16 by 32 feet apart. The Winesaps in the rows alternated with fillers mostly of Missouri Pippins and Wagners and a few Jonathan apple and Elberta peach trees. This orchard has a very good soil for fruit trees and the Winesaps are of good size for their age.

TIME OF THINNING.

Ten trees were selected that had from a fair to a very heavy load of apples which were about three-quarters of an inch in diameter. Six of these trees were thinned on June 16th, 17th and 20th. This was done just as soon after the "June drop" as it was possible to tell what fruit would stick. The earlier in the season after the "June drop" that thinning of the Winesap can be done, the better it will be for the tree and remaining apples.

The mid-summer thinning was done on July 22nd. Only two trees were thinned, and although the per cent. of the better grades was as good as from the June thinned trees, it might not have held good if more trees had been thinned at that time. The extra amount of plant food that is utilized by the apples which remain on an early thinned tree, after part of them have been taken off, induces a growth that could not be made by the same number of apples left on a tree after thinning late in the season. This is one of the chief reasons why thinning of apples should be done just as early as possible. There have been various attempts to thin the bloom instead of the apples, after they have set, but at present no method has been devised whereby this can be successfully done. This would be hard to do, and undesirable, where killing spring frosts are liable to occur.

THINNING WINESAP—SEASON 1910.

Tree No.	No. Apples Thinned Off		Windfalls Before and At Picking Time				Total No. Apples Picked Per Tree		Total No. Borne Per Tree	Thinning Distance in Inches
	Date	No.	Date	Before	At Picking	No. Boxes	Boxes	Apples	Apples	
1	6—16	3167	10—7	93	18	.5	20.5	3391	6669	About 10 except in top
2	6—16	2550	10—7	76	47	.5	21.5	3526	6199	6 to 8
3	6—17	2150	10—7	101	4	.5	18	3134	5389	8
4	6—17	1000	10—8	48	12	.3	10	1908	2968	10 to 12
5	6—17	1980	10—8	58	40	.5	14	2155	4233	About 8
6	5—20	3250	10—8	52	43	.5	14	2036	5381	10
7	7—22	2033	10—8	40	15	.25	12	1711	3799	8 to 10
8	7—22	3060	10—8	75	21	.5	14	2371	5527	6 to 8
Check 1	------	------	10—10	246	133	1.25	26	6293	6672	Not Thinned
Check 2	------	------	10—10	312	71	1.25	16	3249	3632	Not Thinned

RECORD IN PACKING HOUSE.

(NO WINDFALLS TAKEN TO PACKING HOUSE)

Tree No.	No. Picking Boxes	PACKED OUT BOXES GRADED						Total Boxes Culls with Windfalls
		Ex. F.	Ex. C.	Standard	Three Grades Total	Culls	Four Grades Total	
1	20.5	7.5	3	5	15.5	.62	16.12	1.12
2	21.5	7.12	6.5	4.5	18.12	.75	18.87	1.25
3	18	4	5.25	3.66	12.91	1.66	14.57	2.16
4	10	2	1.33	4	7.33	.33	7.66	.63
5	14	3	3.66	3	9.66	.5	10.16	1
6	14	6.5	2	1.87	10.37	.5	10.87	1
7	12	5.5	1	1 12	7.62	.5	8.12	.75
8	14	7.12	1.8	2.5	11.42	.5	11.92	1
Check 1	26	2	0	12	14	6	20	7.25
Check 2	16	3	2	6	11	1.66	12.66	2.91

THE PER CENT. PACKED OUT FOR EACH TREE FOR THE FOUR GRADES.

Tree No.	In Packing House, Not Counting Windfalls					Grand Total No. Packed Out Boxes and Per Cent. for Each Tree, Counting all Windfalls					
	Four Grades Total Boxes	Per Cent. Packed Out in Different Grades				Windfalls—No. Boxes	Total Boxes	Per Cent. for Each Tree			
		Ex. F %	Ex. C %	Stand. %	Culls %			Ex. F %	Ex. C %	Stand. %	Culls %
1	16.12	46.21	18.61	31.01	3.84	.5	16.62	45.12	18.05	30.08	6.75
2	18.87	37.73	34.44	23.84	3.97	.5	19.37	36.77	33.55	23.23	6.45
3	14.57	27.45	36.03	25.12	11.39	.5	15.07	26.54	34 84	24 29	14.33
4	7.66	26.1	17.36	52.21	4.3	.3	7.96	25.12	16.71	50.25	7.91
5	10.16	29.43	36.02	29.43	4.92	.5	10.66	28.07	34.35	28.07	9.40
6	10.87	59.79	18.39	17.2	4.59	.5	11.37	57.17	17.59	16.44	8.80
7	8 12	67.73	12.31	13.79	6.15	.25	8.37	65.71	11.94	13.38	8.96
8	11.92	59.73	15.1	20.97	4.19	.5	12.42	57.33	14.50	20.13	8.05
Check 1	20	10	.....	60	30	1.25	21.25	9.41	.....	56.47	34.12
Check 2	12.66	26.69	15.79	47.39	13.11	1.25	13.91	21.56	14.38	43.13	20.83

AVERAGES.

	Average No. Picking Boxes to Tree	Average No. Packed Out Boxes to Tree					
		Ex. F	Ex. C	Stand.	Total 3 Grades	Total Culls	Total to Tree
Thinned	15 08	5.34	3.07	3.20	11.61	1.11	12.72
Unthinned	eight trees 22.25 two trees	2.5	1	9	12.5	5.8	17.58

OR IN PER CENT.

	Average % of Packed Out Boxes to Tree in Different Grades					
	Ex. F %	Ex. C %	Stand. %	3 Gr'd's %	Culls %	Boxes
Thinned	41.98	24.14	25.15	91.27	8.72	12.72
Unthinned	14.22	5.69	51.19	71.10	28.89	17.58

DISCUSSION OF TABLES.

Windfalls.—In figuring the total per cent. of the different grades borne by each tree, the thinned off apples were not counted. The windfalls were all counted as culls, for it is a well known fact that when an apple falls to the ground, from any cause, it generally bruises so that it has to be thrown into the cull box.

It will be seen that the average number of windfalls per tree before picking, was 68 apples for the thinned and 279 apples for the unthinned trees. The average number of apples which fell to the ground while picking was 25 from the thinned, and 102 from the checks or unthinned trees. The total average number of apples which fell to the ground was 93 from the thinned trees and 381 from the unthinned, making about four times as many fallen apples per tree for the checks or unthinned, as for the thinned trees. The number of apples which fell while picking was 77 less per tree for the thinned trees than for the unthinned. When the apples are in clusters at picking time, it is impossible to keep from dropping some on the ground, and the more clusters there are the greater will be the number that fall. The figures show there were about four times as many apples dropped from the unthinned as from the thinned trees.

Culls.—Apples which come under this head were those less than 2¼ inches in diameter, those badly bruised or scarred, and those very wormy. In connection with this it might be well to state that the Winesaps in the experiment were from 5 to 7 per cent. wormy. This worminess had some effect on the per cent. of boxes packed in the different grades, and as the unthinned fruit was more wormy, because of the clusters affording favorable places for the young codling moth larvae to gain an entrance to the fruit, the number of culls due to codling moth, would be proportionately greater from the unthinned trees.

Many of the apples "culled" were those that were limb-bruised because of their rubbing against some limb. Those apples growing on the terminals of long, slender branches were often badly limb-bruised, caused by being knocked about in the wind. Proper pruning and thinning does away largely with these abrasions.

Thinning Distance.—To thin the fruit on a tree and leave the apples a definite distance apart is a difficult matter. A keen eye and experience are required for the best results. One may think that he is taking off too many apples, or whatever fruit he is thinning, and that he is ruining his crop, but at picking time he generally wishes that he had taken off more. A good motto to go by in thinning is: "Look up, not down." In other words, pay no attention to the apples on the ground, but be sure that every branch is thinned

to such an extent that it will not only be able to properly support a load of mature fruit, but will also be able to grow it to proper size and color. Because one side of a tree is light and the other side heavy with fruit is no reason why the heavy side should not be thinned. The physiology of a tree is such that the food supply for one side or part of it, is largely independent of the other parts. For example, one side or part of a tree may be dead because of the death of the roots which fed that part of the tree. This is perhaps more often true of old trees than of young ones.

It may be seen from the table that the apples of tree No. 1 were thinned to about 10 inches, except in the top, and it was due to this fact that the small apples were found in that portion of the tree. Because it was hard to tell exactly the distance that the fruit was thinned on each tree, the distances given are more or less estimated.

A study of the individual tree is necessary in order that one may be able to thin it in such a manner as to get the best results. Trees of the same variety and age, may vary in their productiveness in the same orchard, and for this reason it is a good plan to study each tree for several seasons to be able to ascertain its wants and requirements. In averaging the total number of apples borne by each tree, it will be seen that this average is about the same for the thinned as for the checks or unthinned trees. These average totals are 5,021 apples for the trees that were thinned, and 5,152 apples for the checks or unthinned trees. These averages per tree include all of the apples that were set at thinning time.

The average per tree for the number of apples at picking time, including all windfalls, was for the thinned 2,622, and for the unthinned or checks 5,152 apples. From these figures it may be seen that about one-half of the apples were removed from thinned trees. The average estimated distance apart of all apples on thinned trees was 8¾ inches. In examining the apples at picking time, it was found that as a rule, better apples, in regard to size and color, were found on limbs where they had been thinned to about 10 inches. It is believed that the very best results from thinning old, heavy bearing Winesap trees, would be obtained by thinning the apples uniformly to a distance of from 9 to 10 inches as soon as possible after the "June drop."

Cost of Thinning.—In this experiment an average of about 750 apples per hour were thinned from the trees. This would make 7,500 apples for a day of ten hours. Counting 2,400 apples to be thinned from a tree, one man would thin 3⅛ trees per day. The cost of thinning a tree, allowing two dollars a day for a man's wages, would be 64 cents. An expert thinner who could take off 1,000 apples an hour would cut this cost down to 48 cents per tree.

DOES THINNING PAY?

It often happens that the fruit grower does not like to do a thing unless he is sure that he will get quick returns for his labor. He so often does not look far enough into the future to regulate and manage certain factors over which he may have control that would insure future returns which would more than pay for any extra effort that he might put forth. From this standpoint it is necessary to consider other phases than that of the net returns of a single year, to tell whether or not thinning pays. These may be stated as follows:

1. Maintaining *the vigor of the trees. 2. Securing annual crops instead of alternate. 3. To be able to produce fruit of maximum size, color and quality.

Maintaining the Vigor.—This is a very important factor, for any fruit tree when injured or impaired in any manner, will not be able so successfully to resist insect, fungus and freezing effects. Thinning annually and uniformly will have much to do in preserving this vitality. Whenever the question is asked an orchardist, "Why is it that this apparently healthy apple tree is not bearing this year?" the chances are that he will answer, either that the fruit or bloom was killed by frost, or that it overbore the year before. It is noticeable, in this connection, that a tree with a heavy bloom will go through the average spring frost with little damage to the crop.

There is no doubt that the orchardist is right when he claims that overbearing one year will cause "shy" blooming the next with some varieties of apples, such as the Jonathan for instance, and the writer has seen the Ben Davis affected in the same way. The Winesap, as a rule, is not a "shy" bloomer, and overbearing may weaken the vitality, causing the tree to grow small, inferior apples, some of which never properly ripen.

The breaking down of limbs is the result of overbearing and can only be avoided by either propping or pruning and thinning. We firmly believe that props have no place in an orchard and when used are only a sign of very poor orchard management. There is no doubt that pruning has a very important place in orchard management and should not, by any means, be neglected. Especially is this true for the young trees. If a tree is properly pruned every year from the time it is set out, the amount of pruning can be decreased somewhat in proportion to the size of the tree when it has become full-grown. The word full-grown is used more or less arbitrarily, but generally conveys the idea that the tree is capable of bearing a full crop. Some think that every apple tree can be thinned

*E. R. Bennett, Storrs, Conn. Experiment Station Report, 1903.

enough with the pruning shears in the winter time, thereby doing away with the necessity of thinning by hand in the summer. These people forget that the plant food that goes to make and mature the apple is manufactured by the leaves and not by the roots of the tree. Keep a tree defoliated in the summer for any length of time and you will kill it. It is not best to obtain all of the leaf surface possible, as would be the case with an unpruned tree, for this would mean wood growth at the expense of fruit, and a greater amount of hand thinning. There would also be too much shade for the fruit and a poor color would be the result. A well balanced and well cared for tree, bearing a good crop of uniform sized apples every year will retain its vigor, while a tree allowed to bear an enormous crop one year and none the next may suffer the consequences of over production.

Securing Annual Crops Instead of Alternate.—A tree will produce quantity at the expense of quality, and at the same time utilize plant food that should be used in making the fruit buds for the next year's bloom. The law of nature is to reproduce its kind and it tends to do it even at the expense of the welfare of the tree. Annual thinning tends to throw a tree into annual bearing. When a tree has been in the habit of bearing alternate crops, it may take some time to induce it to bear every year by thinning. It has been demonstrated in the orchard where this experiment was carried on that by annual thinning the Jonathan can be made to bloom well every year.

Fruit of Maximum Size, Color and Quality.—The total averages, as given in the table found in the different grades, illustrates the points of size and color, for apples have to be of a certain size and a certain color to be packed in the first two grades. The following table illustrates the comparative values of the different grades. The culls were selling at the cannery and evaporator at $7 per ton, or the equal of $0.175 per fifty-pound box.

	Ex. F. Boxes at $1.75	Ex. C. Boxes at $1.50	Stand. Boxes at $0 85	Cull Boxes at $0|75	Cost of Thinning
Thinned -----	5.34-$9.35	3.07-$4.61	3.2 -$2.72	1.11-$0.19	$0.64
Unthinned ----	2.5 -$4.38	1 -$1.50	9. -$7.65	5.08-$0.89	----------
Thinned ------	Gain-$4.97	Gain-$3.11	Loss-$4.93	Loss-$0.70	Loss-$0.64

$8 08—$6 23-$1.85, total gain per tree.

When trees are set 16x32 feet, there are 85 to the acre. A gain of $1.85 per tree would make a total gain of $157.25 to the acre.

This seems strong evidence that thinning the Winesap gives large returns for time and labor expended. The above figures are conservative in at least two respects: 1st. Many of the windfalls which were counted as culls could never have been sold for any purpose; especially was this true of the early dropped windfalls. Also there is much doubt as to whether the amount received for the culls would have paid for the extra labor required in picking, hauling and sorting. 2nd. The extra amount of time that it took to grade the apples from the unthinned trees for packing was considerable. These two expenses would alone almost offset the cost of thinning.

Uniformity of size was very characteristic of the apples from the thinned trees, while the apples from the unthinned ones were of all sizes. (See Fig. 1.)

Better colored fruit was always found on the thinned trees than on the unthinned, due largely to the fact that the fruit on the unthinned trees was crowded and consequently more or less shaded.

The lessened percentage of wormy apples, due to picking and destroying the apples infested by the first brood of worms, would probably be a saving sufficient to largely bear the expense of thinning.

HOW TO THIN.

Study each tree individually and thin so that at picking time the tree will hold up well under a load of uniform, good sized and well colored apples. It takes experience and study to get the very best results from thinning.

The experiment indicates that best results in thinning the Winesap can be attained when the apples are thinned to a distance of from nine to ten inches. It is well to commence at the top of the tree and work down. Perhaps, if there is any difference in distance to be made, it would be better to thin the apples on the lower limbs next to the trunk of the tree a little farther apart on account of there being more shade in this part of a tree. Although some shade is a good thing, as it prevents sun-scalded fruit, it is possible to have too much.

A very good type of thinning shears is shown on the front cover page. Thinning is much more easily done with this instrument than by hand. (Fig. 2 shows how a small branch with a heavy load should be thinned.)

Take off all terminal apples on long, slender branches and break all doubles. Take off all wormy apples and all those that are much smaller than the average. Take off all limb-bruised or badly frost marked apples, and also those that are liable to become limb-bruised as they grow in size. Leave the apples in singles and in

such a position that they can have the best chance to grow in size, color and uniformity, and be as free as possible from blemish.

There is another phase of thinning that would help, and that is the cutting out of every other tree in rows that have the trees so close together that they are crowding each other. Trees, when crowded, are bound to grow upward rather than outward, and if left alone will, in a little while, have most of their fruit bearing wood in the tops. This is truer of peaches, perhaps, than of apples, nevertheless apple trees when crowded cannot do as well as

Figure 2. A three-foot branch before and after thinning.

when they have plenty of room. For this reason it is necessary to cut out every other tree in the row, or the alternates in every row, this depending on the way and the distance the trees are set.

CONCLUSIONS.

1. That thinning of the mature Winesap tree pays in money returns the first year.

2. The more evenly distributed the fruit on the tree the more uniform will be the size and color of the pack.

3. That Winesaps respond to thinning by increased size and better color when thinned as late as July 20.

4. The earlier that thinning can be done, the better will be the returns from the fruit sold and the greater will be the vitality of the tree.

5. The best results are attained in thinning an old Winesap tree, by leaving the apples from 9 to 10 inches apart.

6. That proper pruning, and keeping the trees a proper distance from each other will facilitate thinning.

7. That systematic, annual, uniform thinning done from the time the trees come into bearing, should have much to do in securing an annual crop, thereby doing away with the so-called "off year" bearing of some of the apple varieties.

WINTER AND FROST INJURIES OF FRUIT TREES

The object of the following discussion is to define as nearly as possible the different effects of freezing temperatures upon fruit trees and also to show that these effects often cause the death of fruit trees in Colorado. The subject divides itself into the following heads, namely: winter injury of young trees; winter injury of old trees; and spring frost injuries. In this bulletin, injury to peach and apple trees only will be discussed.

WINTER INJURY OF YOUNG TREES.

This divides itself into two heads, injury done to young apple trees, and that done to young peach trees. Young apple trees are injured for the most part, by freezing at the ground line, and by sun scalding on the trunks. Injury to young apple trees at the ground line is often caused by very low temperatures, resulting in perpendicular cracks which extend on the trunk from the ground line, or just below, upwards to a distance of an inch, or sometimes more. There may be from one to five cracks depending upon the severity of the freeze. In some varieties, such as the Rome Beauty for instance, it is often found that the bark bridges up between these cracks, causing a complete girdling of the trees, which often kills the tree. In most varieties, such as Jonathan and Winesap, the tree generally has strength enough to heal these wounds over so that in a few years they are hardly noticeable. In those cases where there is danger of killing the tree, it would be a good thing to fill the cracks with wax, or it might be of value to heap damp earth around the base of such a tree. If very bad cracks (Fig. 1) were found and taken in time, it might be possible to save the tree by bridge grafting.

FIG. 1. Cracks at base of Rome Beauty caused by winter freezing.
FIG. 2. Winter injury by sun scald on southwest side of Winesap. The affected portion is cut out

In Fig. 2 there will be seen a case of sun scald. This sun scald generally takes place on the southwest side of the tree and, if severe enough, will work around, completely girdling the tree. On young apple trees sun scald is more frequent in winter than it is in summer. Especially is this true when the ground is covered with snow so that the sun's rays are reflected onto the trunks. It is very likely that sunny days and freezing temperatures at night have much to do with sun scald. The injury takes place, as a rule, from the snow line up to the scaffold limbs. In some cases it will be found to extend up on the scaffold limbs, but this latter condition is not so frequent. Prevention of sun scald is better than any remedy that could be prescribed for the trouble, although in severe cases it may be well to bridge graft. Whenever it is possible, it is better to use other methods than bridge grafting in Colorado, as our climate is so dry that it is very hard to keep the scions from drying out. Especially is this true when scions of any length have to be used. The fact that, as a rule, but little sun scald bark is found on the scaffold limbs, is one reason at least why low headed trees are practical. If by some method the ground could be left in such shape in the fall of the year as to prevent snow from lying in a level plane for any length of time, it might do much toward preventing sun scald of young trees. In localities where it is quite sure that the snow fall will be great enough to insure plenty of moisture, it might be well to leave the plowed ground in the fall in a rough state. This would do much to break the snow line. If a green shade crop were plowed under in the fall, this would help in the same way. In those places where the young orchards are bothered by rabbits, a wire netting extending from the ground line to

the scaffold limbs of the tree would not only keep rabbits from gnawing . but would also do much toward breaking the direct and reflected sun rays on the trunks. Wood veneering will answer the same purpose here as wire netting. Never use tar paper. as it not only concentrates the rays of the sun, but has an injurious effect upon the trunks, and in some cases the writer has seen death caused by its use.

It seems that the darker the bark the more liable it is to injuries from sun scald. Whitewashing the trunks of the trees is a very good practice and one that can be used on old trees as well as young. A very good whitewash is the California formula, which is as follows:

Quicklime	30 pounds
Tallow	4 pounds
Salt	5 pounds
Water	enough to make mixture flow well

Prof. W. Paddock says that this makes a tenacious whitewash not easily washed off by rains or removed by other means.

If whitewash is to be applied to the trunks of old trees in the winter time, it is a good thing first to remove all the old, rough bark. In this way many of the injurious insects that are hibernating over winter under this bark will be killed. A rough rasp or file is a very good implement to use in removing the old bark.

In peach orchard districts, where the temperature sometimes falls from 15 to 24 degrees below zero, there is more or less danger of damage being done to peach trees. Especially is this true when the trees are young and the temperature remains low for any length of time. It is sometimes very hard to tell whether considerable damage has been done to trees or not, until late winter, or sometimes it is the first of May before one can be sure whether the trees have withstood the rigorous weather. Perhaps, for peaches, the most common injury is that of killing the fruit buds. But this is not to be dreaded as much as freezing at the crown or ground line, which causes the so-called "collar girdle." Another form of freezing is that beginning at the terminals on the one-year wood and freezing back onto the older wood. This latter form is perhaps more common on older trees than young ones.

For the reason that it is almost impossible to tell the extent of the damage done by freezing until early summer, it is often a good plan to delay pruning until about the first of May. It must be understood that this is when the trees have undergone a severe winter. In other cases perhaps it is better to prune when a tree is dormant, although this is disputed by some of our best orchardists. At

any rate, when severe freezing of the wood has taken place, it is well to wait until the buds have started so that one will know where to prune. Even then peach trees may be so injured as to live months, or in some cases a year or two before dying from the effects of freezing. The so-called "collar girdle" seems to be one that does not show until some time after the freezing has taken place. Trees injured by freezing very often need to be severely cut back. A peach tree will stand a heavier heading back than the apple and for this reason can be pruned very severely, so that it will have a chance to put forth a new growth which, when properly pruned, can take the place of the old head.

One of the very important things to watch in connection with both young apple and peach trees is that of irrigation. It is a very good plan to get all of the growth possible during the early part of the growing season, so that the trees may have a chance to harden off during late summer. In order to do this a young orchard should never be irrigated later than the first of August, and in many cases it would be better if the last summer irrigation took place not later than July 15th, the time varying somewhat with location, kind of soil, etc. Then, if no moisture comes in the latter part of October or first of November, it is a good thing to irrigate. If the trees are not properly ripened or hardened off there is much danger that they will be killed back more or less by the first fall freeze. The writer has seen cases of young peach trees where the terminals were killed back for several inches as early as the middle of October. This was in an orchard where the irrigation was kept up until some time in September. The orchardist's object was to mature a crop of corn that he was raising between the peach tree rows. By spring every peach tree in this orchard was killed to the ground. It often happens that a peach tree has enough vitality and plant food in the trunk and limbs to leaf out and may even bloom, and at the same time it may be so injured by freezing as to be girdled somewhere on the trunk so that in a little while the whole tree dies.

In the case of young apple trees, where the top is frozen back to the trunk, or where the trunk is injured by sun scald and freezing, it is sometimes possible to insert a scion by the cleft or kerf method and thus growing a new top. In top working of this kind be sure that the top is cut off below the injured portion, *i. e.*, have the stock of good, sound wood. It is often possible to top work a young tree in this manner so that a single year's growth would almost equal that which was killed. In a case like this, where a tree has a well established root system, it does not take long to form a good top, but one must be careful about letting it grow too late in the season, as growth like this takes more time to harden off than when slower growth is made. In young trees which have under-

gone severe winters, it is often possible to find the sap wood discolored, generally due to freezing and in some cases traceable by the annual rings to the year of the injury.

WINTER INJURY OF THE OLD TREES.

One form of freezing found on the old, and sometimes young apple trees, is due to "freezing dry." This is thought to result from perhaps two causes. one being lack of moisture in the soil, and the other a deeply frozen condition, stopping all root action. Transpiration, or the loss of water from the limbs and twigs of the tree, goes on in winter as well as in summer. Whenever either or both of the conditions mentioned above exist for any length of time, the results are detrimental to the tree and, if severe enough, may cause death. For this reason it is necessary to irrigate in late fall or early winter. As a rule, the first of November is a desirable time to do this, as it very seldom happens that the soil around the roots freezes enough to do any damage unless the trees are shallow rooted. In this case root freezing might prove to be detrimental. The above statements will hold for the peach as well as for the apple.

There is another form of winter injury to old apple trees that is often found and which, in some cases, is hard to distinguish from injuries due to arsenical poisoning. The distinguishing features are that the injury for the most part is at the crown or ground line primarily and seldom runs down into the root system. The roots, of course, may be affected from this injury, but in such cases the injury would be secondary. The injury takes place in the form of a partial or complete girdling at the ground line. The bark peels off in rough pieces and generally in one spot only. It may extend up to the trunk of the tree for several inches. It depends upon the size of this affected spot whether the injury will prove fatal to the tree or not. In cases of arsenical poisoning the bark becomes corroded to a mealy mass in which the tissues are broken down and may be scraped off from the wood, while with winter injury the bark remains intact and separates at the cambium. The writer has seen cases where fifteen year old Ben Davis trees were killed by this crown line injury. Attempts were made to save the trees by bridge grafting, but as stated before, the scions that had to be used were too long, and dried out before adhesion could take place. These trees were in such a position that undoubtedly more or less ice and snow remained around the bases of them for long periods of time. Although in some cases it would appear that ice around the base of a tree had no detrimental effect, it is not well to allow this, as one can never tell when the conditions are just right for damage to be done. In the fall irrigation it is well to keep the

water in the irrigation furrows and not let it collect around the bases of the trees and freeze. Perhaps there is no harm in allowing it to freeze in the furrow.

The worst injury to old peach trees, other than that of killing them outright, is that of killing the fruit buds. For this reason it is a good plan to delay pruning until one is sure what buds are alive and what are dead. But if this is kept up for any number of years the chances are that the fruit bearing wood will be in the top of the tree and will eventually necessitate a severe heading in.

SPRING FROST INJURIES.

Perhaps there is no injury due to freezing temperatures which gives such immediate results as that of killing frosts in the spring. This too, may have its effect throughout the growing season, but the primary effect is that of a total or partial killing of the bloom, and sometimes that of the set fruit, in the spring. It is not the object in this bulletin to discuss the protection of the orchard from frost. except in a general way.

Some Effects of Frost on the Fruit and Leaves.—Frost may be severe enough to cause only a partial failure of a crop, and when this is the case there is always more or less of the injury seen throughout the season. The most common of these are frost marks consisting of russety patches at both the stem and blossom ends, or in some cases russet bands around the fruit. These russet bands are often seen on the pear. One form of injury, thought to be due to freezing, not often seen, is that of small round russet spots on the surface, which may be in almost any position on the fruit. This has been seen on the Northwest Greening and was supposed at first to be due to spray injury, but upon investigation it was thought to be due to frost injury when the apples were small. It often happens that apples and pears are so injured as to have no seed. Another form of injury to the fruit is that of freezing a part or all of the calyx end, causing the fruit to be deformed. In this latter case the injury generally takes place after the fruit has been pollinated and has set.

The early leaves are often injured by frost and the effects are that they never grow much larger in size than they were at the time of freezing. They may turn yellow and drop during the early season, or they may still hang to the trees, but if they do, they become much thickened, somewhat shriveled, and turn yellow much quicker than the uninjured leaves. As a rule, if the frost is not too late, the damage done to the leaves is not enough to cause any alarm. In some severe cases where most of the leaves are out and all are injured to such an extent as to cause them to drop, there might be some detrimental effects. But, as a rule, the tree will soon throw

out new leaves which will take the place of the injured ones

Prevention of Frost Injuries in General.—As this is a subject that would require a bulletin to be satisfactorily handled, we will give only some of the most important features concerning orchard heating. The following conclusions were drawn after consulting over forty of the leading orchardists of the State who had used orchard heaters:

1. The fact that every orchardist, who had been interviewed upon this subject, claimed that the orchard heater is a good investment as an assurance in the fighting of frost, indicates that the orchard heater has come to stay.

2. The oil heater is usually preferred over the coal, when more than five acres are to be heated, because of its more economical maintenance.

3. On cold, windy nights orchards with low headed trees receive more benefit from the heaters than high headed ones.

4. Good thermometers well tested should be in the orchard as well as on the outside.

5. Careful study of the stage of growth of the fruit buds should be made to ascertain their hardihood against frost injuries.

In regard to the stage of growth of the fruit buds, bloom and set fruit of peaches and apples, as compared to their resistance to frost, the following opinions are given: Prof. W. L. Howard *states that in Missouri fully dormant peach buds can stand 8 or 9 degrees below zero. When appreciably swollen, zero is the danger point. When the buds are showing the pink, they can stand 15 degrees above zero. When the petals are off they stand 30 degrees above zero. For apples, when the petals begin to show, they can possibly stand a temperature of from 20 to 22 degrees above zero. From this stage on their resistance to cold becomes less and less as growth progresses.

Prof. P. J. O'Gara †states that, in the Pacific Northwest, peaches in bud are injured by a temperature of 29 degrees F.; in blossom by 30 degrees, and set fruit by 30 degree F. Apples in bud are injured by a temperature of 27 degrees; in blossom by 29, and set fruit by 30 degrees F.

Prof. O. B. Whipple ‡found that it is doubtful if, in Colorado, a temperature of 30 degrees F. will injure fruit or buds, in any stage of growth. That a temperature of 28 degrees, if of long enough duration to freeze the tissues solid, will kill peaches in

*Reprint from the Annual Report of the Missouri State Board of Horticulture, 1909.

†Farmers' Bulletin No. 401, U. S. Dept. Agr.

‡Fruit Growing in Arid Regions, by Paddock and Whipple. p. 353. The MacMillan Company.

bloom or after the peaches have set. That after the peaches have reached some size they will stand a lower temperature for a short period of time. Peach trees well loaded with buds which show slight traces of pink, have often escaped with a good crop with a minimum temperature of 22 degrees. Fruit buds of apple and pear open far enough to show the flower tips, are seriously injured by temperatures lower than 20 degrees. When they are far enough advanced to show the color at the tips, they are generally only slightly injured by temperatures as low as 25 degrees. When in bloom and after the fruit is set, they will seldom stand temperatures lower than 28 degrees. Cherries, apricots, and most of the plums, will require about the same protection as peaches. Native plums in bloom or with fruit set will often stand a temperature of 25 degrees.

It will be seen from the foregoing that the danger point in temperature varies for the different fruit sections and for the different kinds of fruit. It may also vary in the same locality for different years and several years' observations will be necessary in order to get full data on all the conditions that have to do with resistance of freezing temperatures.

Careful study of the weather conditions should be made when orchard heaters are used. Some money can be made in the saving of fuel by starting and putting out the fires at the proper time. Oil heaters when fired can be put out and relighted instantly, while coal is very hard to relight. A good plan is to commence lighting the heaters when a temperature of 30 degrees is reached. If the temperature can be kept at 29 degrees or above, as a rule, there will be little damage done to the bloom or set fruit. The writer has seen, with systematic handling of the heaters, a temperature of around 21 outside raised to 29 degrees in the orchard. It is thought there is no harm done to the trees in the spring from a small amount of oil spilled in the orchard, nor from the gases, soot, etc., which come from the coal and oil.

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The Colorado Raspberry Industry

BY

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A good type of Cuthbert raspberry bush.

THE COLORADO RASPBERRY INDUSTRY

By R. S. HERRICK AND E. R. BENNETT.

The raspberry is one of the best known small fruits. In its wild state it has been used as food since the beginning of history. This fruit belongs to the family of brambles of which there are many hundred species. The raspberries of commerce are mostly included in three species. These three species are divided between two quite distinct types, the reds and blacks.

The European red raspberry, *Rubus Idaeus,* is little grown in this country. The fruit is similar to the American red raspberry in appearance, of better quality, but the plants are less hardy. The early attempts at red raspberry culture in this country were largely confined to the development of this species but these have never succeeded because the species is not adapted to our climatic conditions.

The American red raspberry, *Rubus strigosus,* is of comparatively recent domestication. In the wild state it is found more or less over the northern and eastern United States. One variety of this species is native in the higher altitudes of the Rocky Mountains. This wild raspberry of the mountains is far superior in quality to the domesticated berry or to the wild berry of the East. Up to the present time however nothing has been done to improve or acclimate the berry to cultivated conditions.

The black raspberry, *Rubus occidentalis,* is also native to the northern and eastern United States. The black raspberry of commerce is practically the same as the wild berries of the fields. This species is commercially the most important of the raspberries.

Another species, *Rubus neglectus,* is a hybrid of the American red and black raspberry. This species is relatively unimportant. It is represented by what is known as the purple cane berries.

The raspberry has reached its greatest commercial importance in the northeastern states. This is because the fruit demands a cool climate and a loose, moist soil with an abundance of humus. In a wild state both the red and black varieties are found at their best on newly cleared timber lands of the eastern and central states. Land from which timber has been removed in the East is nearly always first occupied by the raspberry brambles. After the surface humus becomes more or less exhausted these bushes disappear.

The great drawback to raspberry growing either in a wild or cultivated state is the droughts that are apt to occur at time of ripening. For this reason the culture of this fruit has been to a great extent confined to those regions of sheltered timber lands and plenti-

ful rainfall. The red raspberry seems to be as much at home in the burned over timber lands of the high altitudes of Colorado as in Michigan; consequently we may conclude that the soils of Colorado are as well adapted as in the eastern states.

Comparatively few diseases attack the raspberry in the dry climate of Colorado. The yield and quality of fruit is equal or superior to that of the East.

Raspberry growing has become one of the important industries in several districts of Colorado and it gives promise of proving even more valuable in the future because the conditions for the best development of fruit may be more readily met on the irrigated lands of Colorado than in the uncertain climatic conditions of other parts of the country.

REQUIREMENTS.

Although the raspberry is one of our fruits that can be raised in most any section of the state up to an altitude of ten thousand feet and in various kinds of soil, there are certain requirements that, if followed, will insure its success.

Soils.—The native raspberry of the state is found on mountain sides where there is a good supply of humus. The cultivated plant is grown in soils ranging from a light sandy loam to a heavy clay. On investigation it has been found that the earlier fruit is on the sandier soils, but the better production comes from those plants growing in a heavier soil such as a clay loam. The sub-soil is an important matter as regards drainage. The best subsoil would be that of gravel or sand. With less impermeable sub-soils the site requires more slope to insure proper drainage. The depth of soil that is the best for raspberries is more or less an open question. Perhaps six or eight inches of good surface soil is deep enough for a short lived plantation. There is no doubt but that a soil two or more feet in depth is better for raspberries than a shallower one. The more humus that the soil contains at the time of planting the better will be the result in growth.

Climate.—The different climatic conditions which exist in the state necessitates two distinct methods of handling raspberries. In those sections where the temperature falls to several degrees below zero and remains there for any length of time it is necessary to cover for winter protection. In those sections where the temperature never falls to but around zero it is not necessary to cover either the red or black varieties. Then there are other sections where the red varieties have to be covered and the black do not need winter protection. As far as climate is concerned raspberries will stand the most rigorous

climatic conditions of any of our fruits, if covered for winter protection.

Moisture.—The raspberry requires a medium amount of moisture for its best growth except during the fruiting stage, at which time it requires a maximum amount. For the most part it is not practicable to raise raspberries in Colorado without irrigation. It might be possible to grow them in certain sections where the rainfall is plentiful as compared to the state's average rainfall but it is doubtful whether or not in those sections there would be moisture enough to insure proper growth during the fruiting season.

If one intends to go into the raspberry business it would be well to select a location where a favorable market could be had quite near at hand. Careful selection of the site is necessary as regards climatic conditions, depth and kind of soil, amount of moisture to be had, etc. A southern slope may be warmer during the winter but it may also dry out quicker, and this is quite an important factor for all fruits.

PREPARATION OF THE FUTURE RASPBERRY PLANTATION.

When a fruit plantation of any kind is to be planted on new land it is well at first to get it into the best possible condition. In order to insure the best results it is important that the seed bed be properly made before setting out the plants. Not infrequently fruits of various kinds are set in raw land that has never been plowed except in the rows where the plants were set. In such cases the plants often grow in a stunted way and never acquire the vigor that they should attain.

One of the best crops for growing on raw land is alfalfa. If alfalfa has made a good growth it may be plowed under the second fall and if the soil is poor in humus it would be well to plow under the last cutting. This will do much in bettering the physical condition of raw soil.

It is well to follow the alfalfa with a hoed crop of some kind, such as potatoes, corn, etc. This will help to do away with the weeds and leave the soil in fine condition for planting.

Another reason why land should be cropped before setting out raspberries is that when raw land is first irrigated it most always settles more or less in spots. As irrigation is necessary year after year, it is important that the land has the right slope and has a comparatively smooth surface. The writer knows of no way by which this can be accomplished better than by cropping the land, for two and in some cases four years before setting out fruit of any kind.

Fall plowing is preferable to spring plowing especially when there is a green crop to be plowed under. Earlier spring planting can also be done when the plowing is done in the fall. Irrigation just

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Plenty of barnyard manure will take the place of a green crop. Perhaps barnyard manure does more good if applied after the plants are set than when used before.

DISCUSSION OF VARIETIES.

Although different varieties are more or less localized there are places in Colorado where it is thought that most any kind of raspberry could be grown. In the Loveland district the Marlboro is grown more than any other variety. This is a red raspberry and requires winter protection by covering. At Canon City the black-cap is raised quite extensively. Gregg is the variety most used. Each of these species, that is, the red and black-cap have their advantages. The red raspberry as a rule brings a better price on the market than the black. The black-cap varieties hold up perhaps a little longer in shipment and in many parts of the state do not need winter protection. On the western slope of Colorado the black-cap, red, and the purple cane varieties are found. In some places on the western slope none of these kinds are protected during the winter but it is thought that for the best growth and welfare of the plantation, the red varieties should be covered.

The best red variety for Colorado is undoubtedly the Marlboro on account of its good shipping qualities. The Cuthbert is also a very good variety for home use as it has a better quality and flavor than the Marlboro. Its chief objection is that it is a rather soft berry and will not stand shipment for any great distance. With careful picking and packing the Marlboro will stand up from thirty-six to forty-eight hours depending somewhat on the temperature, while most of the other red varieties go down in from twelve to twenty-four hours. For evaporating purposes the black-caps are better than the red varieties on account of their hardiness. When used for this purpose they can be picked by mechanical means thus doing away with hand picking. So far in Colorado there has been such a demand for raspberries to be used as dessert that it has not been necessary to resort to evaporating. In fact, during the last year there were not enough raspberries raised in Colorado to supply the local market. The following is a list of the different varieties of raspberries which are known to do well in Colorado. The purple cane varieties, as a rule, are the best for canning purposes.

RED RASPBERRIES.

Only very brief descriptios are given of the following varieties of raspberries on accout of the lack of space; these are given in their order of importance.

Marlboro.—This variety is of only ordinary quality but noted for their firmness both on the bushes and hold up well in shipping.

Cuthbert.—A good berry for home use, having fine quality but generally too soft for shipping long distances.

Loudon.—Canes vigorous, quite hardy, and productive. A good berry for local market or home use.

Turner.—This variety is very hardy and vigorous. Fruit, sweet and of excellent flavor.

Golden Queen.—In all characteristics this is a Cuthbert except that it bears yellow fruit. A few for home use are desirable.

BLACK-CAP VARIETIES.

Gregg.—Best known late variety. Very good shipper and an excellent variety for evaporating when picked by hand.

Kansas.—Fruit similar to Gregg ripening a week earlier, juicy, of excellent flavor and firm enough to ship well.

Ohio.—The great evaporating raspberry of the present day. Quality poor as it is very seedy but yields more pounds of evaporated fruit per bushel than any other sorts.

PURPLE CANE VARIETIES.

Shaffer.—An excellent canning variety.

Philadelphia.—This represents the red raspberry more closely than some of the other purple cane varieties. Propogated by suckers, yields but sparingly.

Columbian.—This is of the Shaffer type and ripens a little later.

PROPAGATION.

Propagation of the raspberry varies according to which species it belongs. The red raspberries are propagated from the suckers which come up from the parent root. As a rule most of the red varieties throw up enough suckers to insure plenty of young plants. For this reason careful cultivation has to be resorted to in order to avoid injuring the root system of the old plant. For when it is injured it acts only as a stimulant to throw more shoots and often requires a severe pruning to keep them down. The old plant can be separated by division thus obtaining extra plants for planting purposes, but as a rule this is not as good a plan as to use the young shoots with the roots attached.

The black raspberry is propagated by tip layerage. This is done by covering the tips along the latter part of July or the first of August. They take root at this point and generally establish themselves well enough so that the next spring they can be separated from the parent stock by cutting the cane off near the ground.

The purple cane varieties vary somewhat in their mode of propagation according to the variety. The most of them however resemble the black-cap in this respect and are propagated by tip layerage.

SETTING PLANTS.

It is a good plan to grow the variety which has done the best in that locality. It is better to secure home grown plants when such are available rather than to use plants brought from a distance.

Age of Plants.—It is believed that yearling plants are the most desirable for the new plantation. By this we mean those plants which have grown one full season and not those that were started the summer before. In some cases it is perhaps possible to get good stocky plants which were started the summer before but generally these are small and spindling and have a poor root system.

Time of Setting.—In Colorado the best time to set raspberry plants is in the spring. This should be done just as early as is possible to avoid any damage from severe frosts. As a rule, the middle of April is a good time. For this reason it is well to have the land plowed the fall before.

Distances.—The distances that raspberry growers use in setting out new plantations vary somewhat according to variety and locality. In those localities where the winters are not severe enough to require laying down it is not necessary to plant the rows as far apart as where protection from the winter is required. Where protection is necessary the distance for the red raspberry between the rows is seven feet apart and in the row two feet and eight inches. The distance in the row can be greater than this providing the pin system of laying down is not used. This distance varies from that mentioned up to three and a half feet. In those localities where laying down is not required for winter protection, the distance of five to six feet for the rows and from three to five feet in the rows is used. This enables cultivation to take place both ways. It requires 2333 plants per acre when set two feet eight inches in the row and rows seven feet apart.

The black-cap varieties in those localities where winter protection is not used, should be planted with rows the same distance apart as for the red, that is, about seven feet and about five feet in the row. Where covering of the black-cap is necessary it is better to have them a little closer than this, from three and a half to four feet. This latter distance will require severe pruning of the plants to keep them from forming a hedge row. The purple cane varieties can be the same distances as the black-cap which in habit they so closely resemble.

Method of Setting.—A good method of planting is to have the rows staked off the desired distance from each other and plow a deep furrow where the rows are to be set. Set the plants by hand the de-

sired distance in the row from each other and place some dirt around the roots of each to keep them from drying out. The rest of the dirt can be plowed back with one horse. Irrigation should follow as soon as the plants are set in order to keep them from drying out. If cultivation is to be done both ways it would be well to set the plants in check rows. This would lighten the expense of cultivation especially for large areas.

CULTIVATION AND IRRIGATION.

In those localities where covering is necessary for winter protection there is less need perhaps for an annual plowing as this is done in the fall when covering and in the spring when uncovering. This keeps the soil from forming a hard pan four or five inches below the surface as is often found when only clean cultivation is used. A good rule to follow during the summer is to cultivate after each irrigation except during the fruiting season. This will not only prevent the ground from baking but will often take the place of irrigation. During the fruiting season it is necessary to irrigate some soils almost every other day; for others twice a week is plenty. It is probable that if careful irrigation and cultivation were used during the growing season, it would not be necessary to irrigate so often during the fruiting season. Over irrigation has a tendency to soften the fruit. In running the water between the rows it is not a good plan to have the irrigation furrows too near the plants, as it is hard to cultivate the furrows in when they are too close.

There is a dispute as to whether the plantation should be irrigated and cultivated up to the last of the growing season or whether it is better to allow irrigation and cultivation to cease about the first of August, thus giving the plants a chance to ripen. It is thought that this latter practice is the better. Irrigation can be done the latter part of October or the first part of November. This will enable the plantation to be more easily covered with soil. This late irrigation is also beneficial in keeping the soil moist during the winter.

Cultivation is quite necessary during the growing season to keep down weeds and perhaps more important to keep down suckers in those varieties that are inclined to throw up a great many shoots. Square teeth are used on the cultivator in the place of the round ones in order to cut the shoots off just below the ground. These square teeth can be made by any blacksmith and are one of the best implements to use to keep down suckers. It cannot be emphasized too much that irrigation cannot take the place of cultivation. But on the other hand, it is often possible for cultivation to take the place of irrigation with good results. Frequent hoeing during the season up to the fruiting period is necessary especially where the plants are

not check rowed in order to keep weeds and raspberry shoots from growing in between the hills. It is always better to keep thrifty hills in the row rather than to let them grow together and form a matted row.

WINTER PROTECTION.

As has been stated before it depends largely upon variety and locality whether or not it is necessary to lay the plants down for winter protection. In the Loveland district all varieties are laid down. In the Canon City district and most places on the Western slope the black-caps are hardy and do not need winter protection, while the red raspberries as a rule are covered.

Methods of Protection.—There are two principal methods used by which raspberries can be protected from the winter freezing, namely, that of covering with straw, leaves, etc. and that of covering with earth. As a rule in Colorado the earth covering is the more practical as straw and other material is sometimes scarce.

Raspberries are laid down from the middle of October to the middle of November, depending somewhat on the weather conditions. There are two principal systems used in laying down the plants, namely, first that of pinning, and second that of bending over and throwing dirt on the tips, thus holding them down. The pinning system is done by commencing at the end of the row and pulling the first two hills down so that the tops of each are at the side of the base of the other. They are held in place by pieces of old canes which are broken to about six inches in length and so placed as to hold the canes in a firm position on the right hand side of the base of the plant. In order to do this pinning properly it is necessary to either have canes long enough to overlap when they are laid down or have the hills close enough together. It is always well to have the tops of one plant at the right of the base of the next and to keep this up throughout covering. If this is done uncovering in the spring can be aided by using a right hand plow, to plow at least one furrow away from each row. Another form of holding the plants down until some earth can be placed upon them is that of using a six tined pitch fork and holding the tops in place until earth can be shoveled onto them. By using either the pinning or fork system of holding plants in place, one man can very easily cover his own canes. Placing soil upon the canes to hold them down takes from two to three men. One man bends the canes down and the other two shovel soil upon them. In pulling the canes down into place it is necessary that they lay quite flat on the ground in order to be properly covered, otherwise they are apt to loop in the center causing an air space and the likelihood of their becoming uncovered before spring. See Fig. 1.

Figure 1. Raspberries not properly laid down and covered.

One of the vital phases in the protection of raspberries is that of uncovering in the spring. If uncovered too early they may be caught by late spring frosts and on the other hand, if uncovered late, the buds shoot out into white tender growth which may be killed by hot winds. A good plan would be to commence uncovering to within about one-half an inch of the canes, about the middle of April and to keep this up gradually for some time until the work was completed. This would give a chance for the young growth to harden off so as to resist the change of climatic conditions.

The labor of covering the canes may be facilitated by plowing two furrows on each side of the row before using the shovel. It is a good plan to have a well rounded ridge with plenty of earth on either side to form rather wide bases. This will help to keep the earth from falling off from the top as would be the case with a narrow high ridge. Fig. 2. is an example of well covered rows.

In uncovering the plants in the spring never allow any soil to pile up in the hills or between them, for, if this is allowed it will not be

Figure 2. Raspberries well covered. Note the wide ridges which help to prevent the soil from rolling off of the sides and tops.

long before the rows will be growing on ridges. In order to keep this soil from forming into ridges it is necessary to remove it with a hand hoe from between the hills.

PRUNING.

Perhaps no one thing has as much to do with the life of the raspberry plantation as that of pruning.

Pruning for Red Raspberry.—It is a good plan to prune out all old canes just after the fruiting season and the following fall cut the main canes from three and one half to four feet in length and also remove any small inferior ones. It is, as a rule, better to leave more canes in the fall than you really need. The next spring when the canes are uncovered take out all canes that have been injured or broken and leave only the better ones in each hill. The number to leave depends on the vitality, etc. of the plants. This can best be determined by practice. As a rule, eight to fifteen canes are enough, when properly selected, for each hill. Where red raspberries go through the winter without covering they should be treated the same as black-caps. But it is thought for most districts of Colorado it would be better to

cover and prune as above stated. Mid-summer nipping of red raspberries causes laterals to be thrown out. As a rule this is not a good practice as these laterals are often broken in covering and uncovering. It is better for the fruiting cane to throw out its lateral in the early summer after it has been uncovered. The figure on the front page is a good type of pruning knife for cutting out the old canes.

Pruning of the Black-Caps.—Where the black-cap raspberry does not have to be covered for winter protection the following method should be followed. Cut out all old canes after the fruiting season and at the same time pinch back within three feet of the ground all new canes allowing these to throw out new laterals. In some cases it may be necessary to do this pinching back of new canes before the fruiting season. In this case another pruning is required. It is well to do this before the canes have grown too long. They shoud be pinched back to from eighteen to thirty-six inches from the ground. In the spring go over each hill cutting out all diseaseed or broken canes. Where black-caps have to be laid down for winter protection they can be treated the same as red raspberries as regards pruning.

The true purple cane varieties can be treated about the same as the black-caps which they more closely resemble in habit.

GENERAL MANAGEMENT.

The question is often asked, "Can raspberries be raised successfully in a young orchard?" This depends somewhat on kind of soil and method practiced. It is believed that with a rich, deep soil and with proper management two rows of raspberries, or in some cases three, depending upon the distance the trees are planted, can be raised in a young orchard for four or five years, or until the trees require a great amount of spraying, etc. Never plant raspberries in the tree row as is shown in Fig. 1. In raising anything in an orchard it must be remembered that the trees are primary and everything else secondary. Raspberries require more water than young fruit trees but it is thought that by keeping the water from the trees and watering the raspberries only for a few years, at least, no damage would result from this practice. Fig. 3. shows a raspberry plantation growing between old apple trees. It shows the stunted effect on the raspberries of over shade and crowding.

Fertilizing.—The best way to fertilize a raspberry plantation is to haul manure during the winter in between the covered rows. This manure can often be of a rough nature and in some cases it is thought to be better than when it is fine and well rotted. Perhaps the reason for this is that its physical nature is more valuable than fine manure. When this is placed in between the rows it is covered the next spring by uncovering the hills. In this condition it soon decays and becomes incorporated with the soil.

Figure 3. Raspberries growing in a fifteen year old apple orchard. Note stunted effect on the raspberries next to the trees.

Life of Plantation.—Eastern authorities claim that the best results are obtained when the plantation is not allowed to grow longer than six or seven years. In Colorado it is thought that with the proper management and care a raspberry plantation will last from twelve to fifteen years. There are in the Loveland district at the present time plantations twelve years old and these seem to be as thrifty as younger ones. It is hard to give the life of a plantation as this depends largely upon the care given it.

YIELDS.

Yields for the raspberry plantation vary somewhat from year to year, it depends largely on the vigor and growth of the plant. An average yield for the black-cap raspberry is two hundred and seventy crates per acre; that of the red varieties is about three hundred seventy-five crates per acre. When we speak of crates we mean those which contain twenty-four pint boxes. In some cases the black raspberries are crated in quart boxes but unless for local market it is better to place them in pint boxes as the raspberries will hold up better. As a rule

the raspberry plantation will not come into bearing to any great extent until the third season.

HARVESTING.

Unless raspberries are picked for evaporating purposes they are picked direct from the bushes into pint boxes; these are placed in a hand carrier which holds six boxes and carried direct to the packing house. It has been found that carriers holding not more than six boxes are better than those holding more on account of their not allowing the berries to remain in the sun for any length of time. After the berries are picked they should be kept as cool as possible until marketed.

Markets.—When a good price can be obtained it is better to sell at a local market than to ship. Good markets for the berries grown on the western slope are found in the nearby mountain towns. In fact during the past year there were not enough berries grown to supply many of the local markets of the western slope. The berries of the Loveland district are handled by an association which finds various markets of which Denver is the principal one. Some berries are shipped out of the state.

Values.—The amount received per crate varies somewhat according to amount grown and place of market. The average cost for the made up crate is about fifteen cents each. The cost for picking and carrying to packing house is about thirty cents a crate. The gross value received for an acre of red raspberries for the average year would run from four to six hundred dollars. The average expense, including cultivation, irrigation, pruning, covering, picking and packing is from one hundred twenty-five to one hundred fifty dollars per acre. This would leave a net gain of two hundred fifty to four hundred seventy-five dollars for red raspberries and two hundred to three hundred fifty for black-caps per acre.

POSSIBILITIES OF THE INDUSTRY.

There is no doubt but that more raspberries could be grown in those localities where they are already growing and still have good markets. It is believed that there is a large field open for raspberries that can be evaporated. There is no doubt that raspberry growing properly managed can be made to be a paying proposition. There is no reason why every farm should not have a few well cared for bushes in its home garden. As has been stated before, raspberries will grow on a variety of soils and at various altitudes. Of course it might not be profitable to raise them on a large scale as above stated, but there is no reason why a few could not be raised for home use. With good railroad facilities and proper air cooled cars, raspberries can be shipped long distances. Properly air cooled cars are better for raspberries than ice cooled ones as raspberries when ice cooled soon go down when put on the market.

DISEASES.*

Raspberries in Colorado are not troubled with many fungus diseases, for the reason that the climate is too dry for the spread of such troubles as affect the canes above ground.

ANTHRACNOSE.

This can be detected by gray discolored spots found on the canes above ground. When these spots become very numerous they may cause death or greatly weaken the plant. The disease is a surface one, namely, it lives on and in the bark.

Treatment.—Affected old wood should be removed and burned as soon as the fruiting season is over. In setting out new plantations careful inspection of the plants should be made to avoid any with diseased canes. Spraying may be done with one-half strength Bordeaux or self-boiled lime sulfur. In this case it must be remembered that the mycelium lives over winter in the canes, and that spraying can only prevent the germination of spores as they are produced. Black raspberries are perhaps more susceptible to the trouble than the red varieties.

ORANGE RUST.

This disease is detected by the orange-red color on the under side of the leaves. This discoloration is due to the abundance of sori, which produce the orange-red spores by means of which the disease is spread from plant to plant. The mycelium of the fungus which corresponds to the roots of higher plants lives through the winter on the canes and roots of the raspberry. For this reason spraying is not very beneficial for its control. This disease is found more often on blackberries than on raspberries. Black raspberries are more susceptible to it than the red varieties.

Treatment.—All diseased plants as soon as discovered should be dug up and burned.

CROWN GALL.

This disease, caused by bacteria, is characterized by a rough knotty growth around the base or on the roots of the plant.

The most satisfactory treatment for this trouble is to avoid planting any diseased stock. When found in the plantation take out diseased plants and destroy.

CANE BLIGHT.

This disease has been thought for many years to have been winter injury. It is now thought to be a fungus trouble and is being worked on by Prof. W. G. Sackett of this station.

*The accounts of these diseases are taken largely from Card's "Bush Fruits."

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By E. R. BENNETT

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GARDEN NOTES, 1910

By E. R. BENNETT

The garden proposition in Colorado, differs materially from that in the East. It is always a question in a new country as to what will succeed, and what fail. Many people have thought that because of the high altitude of Colorado, few of the garden crops that succeed in the East could be grown here. In fact this idea has been so prevalent that for years many of the ranchmen in the higher altitudes of the State, have lived on canned goods and have freighted potatoes from distant points at four cents per pound, when vegetables, (potatoes in particular), could have been grown better on their ranches than in most places in the East, or even in the lower altitudes of Colorado. Different places in Colorado differ so materially in altitude, and therefore in temperature and rainfall, that it is impossible for anyone to give definite directions, or make definite statements as to what may be done in the State as a whole. Even when certain truck crops have been failures in many places, we cannot conclude that the crop may not grow satisfactorily in a given place until we have tried all the methods possible for its culture. In other words, because a given crop will not grow as handled in Iowa or Ohio, it does not necessarily follow that it cannot be grown, even more successfully, here than there, when we know how to adapt the culture of the plant to our conditions. Many strange discoveries have been made in the State along these lines. For instance, it has been found that cauliflower, cabbage and potatoes may reach the acme of productiveness and quality in places where it was thought almost no crops of these kinds could be grown. Because of these peculiar conditions, it has been thought best, particularly for the benefit of new comers in the State, to discuss the possibilities of growing the various garden crops and the methods which we believe to be best adapted to our conditions. It must be remembered that the work done along these lines, at this Station, cannot be taken as a guide, other than in a general way for similar work in other parts of the State. Almost no two places have the same conditions, and methods employed must be changed accordingly.

During the season of 1910, as many as possible of the annual truck crops adapted to Colorado conditions, have been grown in the gardens of the State Agricultural Experiment Station.

In the work of truck gardening, that has been taken up at the Experiment Station, two ideas are being kept in mind. First the truck crop from a commercial standpoint is considered. This includes all the crops such as cabbage, cauliflower, celery and the like, that are grown for local markets, and also for shipping to

distant markets. These crops are adapted to certain districts and from a commercial standpoint are not adapted to all districts. On the other hand, the truck crops for the home garden may be grown in practically all parts of the State, even though certain ones are not sufficiently adapted to the conditions to produce a maximum of yield and quality. For this reason, we will take up the various vegetables that are in any way adapted to our climate in the alphabetical order, as a matter of convenience, rather than in the order of their importance.

Asparagus.—Asparagus, is one of the most satisfactory crops for the gardens of Colorado. There are comparatively few troubles or pests that interfere with growing this crop in the home garden. In fact, the vegetable easily becomes a weed and may be found growing wild along the creeks and ditches in nearly all parts of the State. There is no reason why every garden should not have a sufficient supply for family use. Whether this vegetable may be grown for a canning proposition, we are not prepared to say. An experiment is now under way to demonstrate this point.

April 12, 1910, about one-tenth of an acre in the College garden was sown to three of the leading varieties of asparagus, i. e. Conovers Colossal, Palmetto, and Barr's Mammoth. Asparagus is slow in germinating. Five weeks elapsed before this seed germinated sufficiently to be seen. It has been thought that asparagus would not do well in this climate. This, however, has made a perfect stand and has grown as well as could be expected at any place. In fact, some of these plants have attained a heighth of more than two feet. At present, the one year roots are being dug for storage and planting next spring. The yield will not be less than 15,000 plants, or at the rate of 150,000 plants per acre. The culture of asparagus for the garden is very simple. It is only necessary to have the soil thoroughly prepared by deep plowing, and well fertilized by mixing with the soil not fewer than twenty to thirty loads of decomposed stable manure per acre. If the asparagus is to be planted in a small plot in the garden, the plants may be set in early spring in the ground in a trench, with the plants from one foot to eighteen inches apart. The plants should be set in a trench at least six inches deep, and covered with not more than two inches of soil at the time of setting. The roots should be spread out in the bottom of the trench with the crowns up. During the season, the trenches may be gradually filled so as to level the ground. When frost kills the tops in the fall they should be cut, and when sufficiently dry should be burned. This will help destroy the insects and fungus pests that trouble the plants. After the plot is cleared, it should be covered with a good coat of stable manure, which should be harrowed into the soil the following spring.

Beets.—All the different varieties of beets, including table beets, mangel wurzels, and sugar beets do well in Colorado. The table beets are easily grown. For early growing they should be planted as early in the spring as the soil can be worked. In high altitudes these are good for table use even into the winter. For the lower altitudes second plantings should be made in June, as those planted early in the season tend to overgrow and become pithy. No particular pests trouble the beets to any extent. The beets in the College garden were ready for market during the months of June and July.

Brussels Sprouts.—One of the vegetables that is almost unknown in the State, but is particularly adapted to the climate of Colorado is the Brussels Sprout. This vegetable is to all intents and purposes a cabbage and may be grown in the same manner as the cabbage. This plant instead of forming a single terminal bud or head forms small heads in the axil of the leaves. For success with this vegetable, it is best to grow it from seeds in hot beds or cold frames, and transplant to the open ground as soon as the weather will permit. The culture is the same as for the cabbage, and insect pests that work on cabbage also work on this plant the same as on cabbage, except that the Green Aphis is more prone to attack the sprout than cabbage. For treatment see cabbage.

Beans.—Theoretically, the bean family should be well adapted to the dry climate of Colorado. It has been found at least in Northern Colorado that the bean has more serious insect enemies than in most other parts of the country. Ordinarily the crop can be grown satisfactorily when the depredations of the striped flea beetle, and lady beetle can be controlled. Care must be taken in the culture of beans not to give more water than is necessary for the development of the plants.

Cabbage.—The cabbage is well adapted to Colorado conditions, particularly the higher altitudes. Growing this crop is becoming one of the commercial industries of the Greeley, Fort Collins, and Denver districts. Owing to the bulkiness of the crop, it has not been grown to any great extent in the mountain valleys of the State, although it is as well or better adapted to those conditions as on the warmer lands of the plains. Early cabbage should be started in cold frames or hot beds, and may be transplanted to the field or garden as soon as the soil can be worked in the spring, provided the plants have been sufficiently hardened off by exposure to the cold. In the College gardens, the Winningstadt variety of cabbage was set May 9th. These cabbage were ready for market the middle of July. Practically every plant made a firm head that weighed from two to four pounds. Cabbage for late use should be set in the field from the latter part of May until the first of July,

depending on the length of season of the place. At Fort Collins Cross cabbage set from the 25th of May until the 5th of July make a crop that is usually matured at the end of the growing season. For market cabbage, it is best to set plants sufficiently close to keep the size of the heads down to five pounds. At Greeley, where 50,000 pounds per acre have been grown, these cabbages are set in rows from 24 to 28 inches apart, and about 14 inches apart in the row; thus using 12,000 to 14,000 plants per acre. Cabbage require a maximum of fertility, particularly of nitrogen.

Two serious cabbage insects are found in Colorado. The most serious one is the so-called cabbage worm, the larva of a white butterfly. In reality there are two species of these worms. Their habits are so nearly alike, however, that they may be treated as one. The best remedy for these worms is to dust on the plants a light application of Paris Green or some of the other arsenical mixtures diluted with flour or lime. If this work is done before the plants are too large, there will be no danger from poisoning either human beings or stock. The green aphis is also frequently destructive to the cabbages. These are best controlled by spraying the plants when the aphis first attacks them, with some contact poison as tobacco decoction or kerosene emulsion. Ordinarily these aphids do not cause sufficient injury to warrant any treatment.

Cauliflower.—Cauliflower is one of the crops that is especially adapted to Colorado conditions, and should be in every garden, even if not for commercial purposes. Cauliflower matures even at an altitude of 8,500 feet. For the past three years this crop has been experimented with in a small way at the Agricultural College and in various parts of the State. This vegetable is peculiar in its demands of soil, climate, etc. In the East, where it is grown for market purposes, it is thought to be doing well if one-half the plants make heads that weigh from one to two pounds. In the high altitudes of Colorado, as in the San Luis Valley, Middle Park, and Aspen, it is not uncommon to find heads that measure 12 to 14 inches in diameter and weigh six to eight pounds. We believe this vegetable in a short time will be grown, not only for home use, but for shipping East to the big markets of the United States. The only difficulty in growing cauliflower in mountain districts is that where gardens or fields are near uncultivated areas, the prairie dogs, ground squirrels, and other small animals are apt to find the vegetables toothsome and are not willing to wait until the crop is ready for harvest.

During the season of 1910, plants were grown at the Experiment Station for experiments in different parts of the State. About 1,000 of these plants were sent to Del Norte. About the same to Grand county, and an equal number was set in the fields

of Fort Collins. Owing to accidents, neither of the lots sent out proved as satisfactory as was hoped. Better than 90% of those that were planted at Fort Collins made marketable heads. Two varieties, Early Snow Ball, and Extra Early Dwarf Erfurt, were used. The late planting was set June 15th and 16th. Up to the present, from one-tenth of an acre of cauliflower 785 pounds have been sold, bringing $42.30. A part of the crop is being held in storage to determine the advisability of keeping cauliflower after the season closes. Cauliflower demands cool weather and a soil that is fairly strong in nitrogen and also well supplied with phosphorus and potassium. The culture for this vegetable is the same as for cabbage, with the additional work of going through the field every day or two after the heads begin to form and tieing the leaves together to prevent the small white heads from coloring. If this is neglected until the head is colored by the sun, the vegetable is injured both for market and family purposes.

Corn.—Corn is a crop that is not well adapted to Colorado, except in the lower altitudes. Corn, requires warm days and nights to make its best development. While it is not advised to grow corn for market purposes, it may be grown in the home garden satisfactorily, except in the higher altitudes. The culture is the same as in other districts. It is well to give corn as little water as possible, as over watering serves to retard the maturity of the corn. The worst enemy of the corn is the so-called boll weevil, or corn worm, which feeds on the immature grain in the husks. No remedy is known for this insect. A succession may be maintained from the latter part of July until frost, by planting such varieties as Corey, or Catawba, for early, Crosby's 12 Row, second crop, and Country Gentleman, for late. At Fort Collins, these three varieties did very well during the past season. Stowell's Evergreen and like varieties are too late to be satisfactory with our length of season.

Celery.—Celery is one of the crops that is not only being grown for home use, but is being extensively grown in Colorado for market. Until within a comparatively short time, it was thought that celery could not be grown in the so-called arid West. It has been found, however, that celery not only can be grown in the West, but that the texture and flavor of Colorado celery is much superior to that grown in either Michigan or California. The celery crop this year in the so-called Denver district will probably amount to 400 cars. This does not include that grown in the Pueblo district, or for numerous markets in other parts of the State. There is no reason why celery should not be grown in every garden. Considerable complaint has been made by celery growers that the tendency of the plant to make seed stalks the first year is a serious

menace to the industry in the State. As a working hypothesis we have assumed that this trouble is due to some of the changes which the plant has undergone in being brought from a humid to a dry climate. In order to investigate this, a small area of both early and late celery was set in the College gardens at Fort Collins. The plants for this experiment were sown in flats in the green house, then pricked from the flats as soon as large enough into benches, 1½ to 2 inches apart each way. This gave sound, stocky plants for setting in the field. Great care was taken from the time the seed was sown that these plants did not suffer for water. Plants were set in the field May 27th and 28th. This date is rather early for Giant Pascall, which is intended for late crop, but was set early in order to induce the plants to go to seed if there was any tendency in that direction. The Golden Self Blanching, was set on either side of a ditch, making two rows about 12 inches apart. Plants were set 8 inches apart in rows. The Giant Pascall was set in single rows six feet apart, eight inches apart in the row. These plots were given clean cultivation at intervals of about one week, with a twelve tooth Planet Junior cultivator. The soil in these plots was kept thoroughly moist. In order to do this, irrigation was given at intervals of from three to five days during the whole summer. This kept the soil more moist than would be desirable for most plants. The Golden Self Blanching was bleached by tieing up the plants individually with old news papers. This method of bleaching proved satisfactory, except where the papers were tied so tightly that the new shoots in the center of the plant were prevented from making their way to the top. In these cases the new shoots doubled up and in crowding started decay. No plants of this variety showed any signs of sending up seed stalks. Nearly all of this was marketed during August. The Giant Pascall was left to grow until rather late in the season. In September furrows were turned to the rows and left for two or three weeks, then early in October the larger part of the plot was taken up and set in a trench for bleaching. This trench was prepared by throwing out a double furrow with a plow and then shoveling out the loose soil so the trench was made about 18 inches deep, and two feet wide. In this the celery was trenched, three plants wide and as close together lengthwise in the trench as the roots of the plant would permit. After setting in the trench water was allowed to run through the trench to firm the soil around the roots. The trench was then covered with corn stalks, and later with straw, old tomato vines and earth. A part of the plot was left where grown. These plants were banked sufficiently high to bleach, then as cold weather approached were covered with tomato vines, straw, etc. A few plants were also taken from the soil and placed in half barrels in the

cellar. This system may be utilized where only a few plants are used, and cool cellar room is available. Although the Giant Pascall made large plants because of having a longer season for growth than is usually desirable for the crop, there were but four or five plants in the whole plot that showed any tendency to go to seed. This would indicate that the cause of celery going to seed prematurely in Colorado is because of drying out of the soil sometime during the growing season. Celery in its natural condition grows in swamps, in other words it is a semi-aquatic plant. It is also a biennial, that is, it should make growth in one season, and develop seed the next the same as the carrot, parsnip, etc. The theory is that, in Colorado, the growth of the plants becomes checked by lack of water sometime during the summer season. This corresponds to the resting season over winter in its natural habitat. When growth starts again after the check the plant sends up its seed stalk. This experiment has not been carried far enough to demonstrate this theory beyond a doubt, but we believe that at least a large part of the trouble experienced by Colorado growers comes from this cause.

Celery growers in Colorado are troubled very little with fungus diseases or insect pests. Occasionally we hear of trouble from decay of the stem. This is undoubtedly caused by fungi. This has not been serious enough up to the present time, however, to lead to any particular investigation of the subject. Celery rust occasionally occurs, but this is not ordinarily serious. Few insects give any trouble.

Cucumber.—The cucumber is a semi-tropical vegetable, and is not supposed to be very well adapted to Colorado conditions. For all places, except the very high altitude, however, this vegetable may be grown with perfect success. While the cool nights are not particularly favorable to the growth of the cucumber, the absence of diseases that cause trouble in other places offset this difficulty to such an extent that the yields are on the whole practically as good as in the so-called cucumber districts of the East. The cucumber needs considerable moisture, and yet care should be taken not to cause a cooling of the soil from too frequent or heavy irrigation. In order to avoid this while the plants are small, the harrow should follow as quickly as possible after irrigation. Where the season is short, the seed should be planted early. The early varieties are to be recommended rather than the larger growing late varieties. The greatest danger to the crop is from poor germination of the seed, owing to the cool nights in the spring. It is well to plant plenty of seed and depend on thinning the plants down to the required number. In the Experiment Station plots, both Coy's Cumberland, and the Fort Hook Famous cucumbers made

good growth until the heavy frost of August 24th, killed the vines.

Egg Plant.—The Egg Plant is one of the least known garden vegetables and one that deserves being better known. This plant is related to the tomato, and requires the same conditions to make its best growth. As it is a warm climate vegetable, it is best to start the plants in the green house or hotbed and have them in blossom when the weather will permit setting in the field. This, at the altitude of Fort Collins, is usually about May 25th to June 10th. These plants should be given as little water as possible and frequent shallow culture. In the Experiment Station plots, Black Beauty proved to be the most valuable variety. Plants may be set two feet apart with rows three feet apart. The little black flea beetle and striped potato beetle are the most serious insect pests of this vegetable. The best remedy found in our plots was to spray the plants with a rather strong application of arsenate of lead. This should be done as fast as the plants are set out, as the flea beetle is apt to be at its worst about the time the plants are ready to be set in the field.

Melon.—Melon growing in Colorado, is so well known that little need be said in regard to it. The melon requires a warm climate and thrives best on a sandy loam soil. The Arkansas Valley district has been noted for several years for its high quality melons. Other sections of the State, notably the Lower Grand Valley and the Uncompahgre Valley, are rivaling the Rocky Ford district. The Greeley district is also producing melons in a commercial way. The soil of Fort Collins is not well adapted to melon culture, and none have been tried in the Experiment Station gardens.

Onion.—The onion is another vegetable that is becoming of commercial importance in various districts of the State. The requirements for the onion are rich loamy soil that can be easily irrigated and worked, and where sufficient stable manure can be obtained to keep the land in the very best condition. For this reason the onion industry is largely confined to areas close to the cities of the State. The greatest drawback to onion growing is the uncertainty of the market. The yields in the State are fairly uniform, and failures are rare. Yields of 300 to 400 sacks, that is, 600 to 800 bushels are not uncommon, but the average is much less than this. The onion requires a fairly long season to mature, therefore is best planted as early in the season as possible. In fact onion seed may be planted in the fall. In the Uncompahgre Valley where the spring is early the seed is frequently sown in February. The ground should be prepared by being preceeded by potatoes or some other hoed crop that will free the land from coarse vegetable fiber and weeds. It should be thoroughly harrowed and leveled

after being plowed, so as to make a fine smooth seed bed. Two systems of growing are used in the State. One, the flat system has rows 12 to 14 inches apart. The other is known as the double row system. That is two rows are close together, with a wider space between. In the Greeley district, irrigation is given by means of flooding. Few diseases trouble the onion crop. Occasionally some loss is sustained from onion rot. A small insect known as "thrips" cause considerable injury to the onion in this State. This insect is so small as not to be ordinarily noticed. A grayish appearance of the leaves and stems; together with a tendency of the leaves to twist, indicate the presence of this insect. This pest is not easily destroyed. About the only means of control is by spraying with some contact insecticide as black leaf sheep dip or a soluble oil. These are seldom very satisfactory, owing to the fact that the insects are for the most part between the leaves, where they are protected from the spray. The varieties mostly grown in the State are the Red Globe, Red Wethersfield, Yellow Globe Danvers, White Globe, and Prize Taker. Onions for family use may be grown in all altitudes and soils of the State. In heavy soils there may be trouble from the seed not being able to prick through the crust. This may be overcome by keeping the soil moist at the time plants are appearing through the ground. In keeping onions for winter, it is best to have them in a cool dry place.

Peas.—Peas are well adapted to practically all districts of Colorado. Northern Colorado is becoming noted for its production of the garden pea for canning purposes. Factories have been established at Longmont, Loveland, and Greeley. The cultivation of this plant is very simple. For garden use it only need be planted early in spring, in drills from two to four inches deep. The wrinkled varieties are somewhat prone to rot in the ground when planted in heavy soil. Few insects or plant diseases trouble peas in Colorado.

Pepper.—The pepper is similar to the egg plant and tomato, so far as soil requirements are concerned. The plant does its best in a rich warm soil. It may be grown, however, in any of the agricultural districts of the State, provided the plants are started early enough to have good sized plants to set when the soil is sufficiently warmed for planting in the field. The seed of the pepper is very slow to germinate, so that plants should be started earlier than for tomato, or cabbage.

Salsify.—This vegetable is comparatively little known, but is desirable as a winter and spring vegetable and is recommended for the home garden. The culture of this plant is very simple. Seed may be sown in drills in the garden at any distance apart that may be desired. The seeds are almost sure to grow, so that a good stand

may be expected. In the fall the roots may be dug and stored in the cellar, or left in the ground until wanted for use. When stored in the cellar they should be covered with soil or sand to prevent shriveling. It is thought by some that freezing improves the quality of the root. Rust frequently attacks the leaves of this plant, but is not usually serious enough to make an appreciable difference in the size of the roots.

Squash.—The squash is somewhat uncertain from a standpoint of production. Some years this vegetable produces so heavily as to be exceedingly profitable, even though the price is not high. Other years the yield is scant. This seems to be more a matter of the season, than from any organic difficulty. The culture of the squash is simple. A warm dry soil is most favorable to its development. Some particularly good specimens of Warted Hubbard, have been grown in Northern Colorado districts. The smaller varieties as Burpee's Ford Hook, are better adapted to the higher altitude and short seasons. One of the worst enemies of the squash is the so-called squash bug. This insect is hard to destroy as it cannot be poisoned. The best remedy, where only a few plants are grown, as in the garden, is to lay pieces of boards on the ground near the plants. The insects will collect under these boards during the night, and may be killed early in the morning.

Tomato.—Tomato growing in Colorado is becoming one of the agricultural industries. This crop has been grown in the Arkansas Valley for quite a number of years, but in the past few years, tomatoes have been grown in the Northern Colorado district from Denver to Greeley for canning purposes. Until recently, nearly all the canned tomatoes of commerce were put up in the eastern states, as Michigan, Delaware, and New Jersey. There the seasons are somewhat more favorable for securing larger yields than in Colorado. However, the yield here is oftentimes equally as good as in the eastern states, and the quality is superior. The tomato thrives in a warm, sandy soil. For that reason this plant demands frequent shallow cultivation. Tomato growing in a commercial way is confined to the lower altitudes in the State. For home use this vegetable may be grown at an altitude of 7,000 to 8,000 feet. In the high altitudes, particular care should be taken to have the plants as large as possible when the ground is ready for setting in the open field. In the Experiment Station gardens, tomatoes were set this year on several different dates. The first setting, made May 10th, was injured by the freeze of May 16th to such an extent that it was necessary to reset plants although the plants first set were well hardened. The second setting was made May 25th. June 4th, two rows of Earlina plants were set that had been grown in six inch pots in the green house. These toma-

toes were in blossom at time of setting, and were not disturbed sufficiently to check the growth. The first tomatoes picked, July 23rd, were from this plot. June 15th another plot of Earlina tomatoes was set. These plants being set so late, never reached a sufficient size at maturity to make the yield that the earlier set plants made. The area of the whole plot was 28/100 of an acre. From this two and one-half tons of tomatoes were picked. The soil of these plots is not well adapted to tomatoes, nor is the climate of Fort Collins considered to be as well adapted as places farther out on the plains. As a result, few tomatoes are planted in this district, and prices are always higher than in Greeley or the other canning centers. For this reason it is an incentive for the enterprizing gardener to grow this vegetable where it is not ordinarily grown. For the high altitude, it is best to select the earliest maturing varieties as Burpee's Early, Spark's Earliana, June Pink, etc. The seed should be started in the green house or hot bed about April 1st. As soon as the plants are sufficiently large to prick out, they should be put, either in other flats one or one and one-half inches apart, or they may be transplanted directly to the hot bed or cold frame as the case may be. They should be, at least, one inch apart, and two inches apart each way is better. These plants should be from six to ten inches high when set in the open ground. If space is available so that plants may be grown individually in four to six inch pots, two or three weeks may be gained in securing early fruits. In any case, great care must be exercised to see that the plants are thoroughly hardened by exposure to the outside air, before being set in the field. Otherwise, a cold wind even several degrees above freezing, when first set, will frequently kill the plants. On the Eastern slope, the potato flea beetle, and the striped potato beetle are serious pests to the tomato. Our experience in this line so far has led us to favor spraying the tomato plants with a strong mixture of arsenate of lead and water, as fast as the plants are set in the ground. This either prevents the insects from working, or kills them if they attack the plants. None of the leaf fungi that are so destructive to the tomato in the East are troublesome in Colorado, nor is there any serious trouble from rotting of the fruit. One soil fungus, Fuserium, occasionally causes losses in the fields. As yet, we are not certain whether this fungus is native in the soils, or is carried to the fields with the plants from the cold frames. The first indication of the trouble is a yellowing and withering of the leaves, followed by shriveling of the plant. If the plant be examined, it will be found that the stem under the ground and above ground also is discolored throughout the vascular system, or sap wood. There is no known remedy for this disease. It may be partly prevented by making sure that the seeds are sown and

plants grown in soil which has not grown tomatoes before, and in rotating the crops, so that tomatoes do not follow tomatoes.

A CABBAGE BREEDING EXPERIMENT.

The Cross cabbage, which is extensively grown in Greeley for shipping, is believed to be an accidental cross between the Winningstadt, and Henderson's Flat Dutch. This cabbage is globe shape in form, and is about half way in season between its two parents. Since the origin of this variety at Greeley by Mr. John Levy, the seed has been grown at that place, so that the variety has been kept practically as first introduced. This cabbage has proved very desirable in the district, but has had one serious failing. Great care has been exercised by those who grow the seed to select heads that were true to type for growing the seed. Notwithstanding this precaution, there is quite a per cent. of the crop that has reverted each year to one or the other of the parents, that is, there are always in the field, many heads that are flattened as the Flat Dutch, and many that are pointed as the Winningstadt. Some of the growers have laid this to uncongenial soil or climatic conditions under which the cabbages were grown. According to Mendel's law, some of these plants should have an inherited tendency to revert each year to the original parentage. In order to ascertain if this principal were true with cabbages, and also to eliminate the trouble if possible, an experiment was started a year ago. First, individual heads of this type were selected in the fall of 1908 for growing seed the following year. In the spring of 1909, several of these heads were planted separately in different places where there would be no chances for the seed to cross pollinate. The rest of the heads were planted in a single row in a garden. All the plants that were set by themselves were sterile or practically so; only a few small seed being developed. Seed was saved from all of the other plants separately, as well as from the several plants from a field at Greeley. These seed were sown separately in the spring of 1910. Later they were transplanted to the field, and stakes set so as to mark off the progeny of each separate plant. Some interesting and valuable results have followed. Of the fifty plants whose progeny was set in the field, only four plots produced heads that were all true to the Cross type. Great variations occurred in the rest of the plots. Some were pointed, following the Winningstadt type, both in shape and earliness; others followed the Flat Dutch, the other parent. In many plots flat, pointed and globe cabbages all came from the same plant. The plants from the plots that were all true to the type have been saved for further experiment, as have also some of the heads of good type from the plots that had various types. Theoretically these plants that are all true to type this year, should continue true to this type. If this proves true, the trouble from changing the type of head will be at an end.

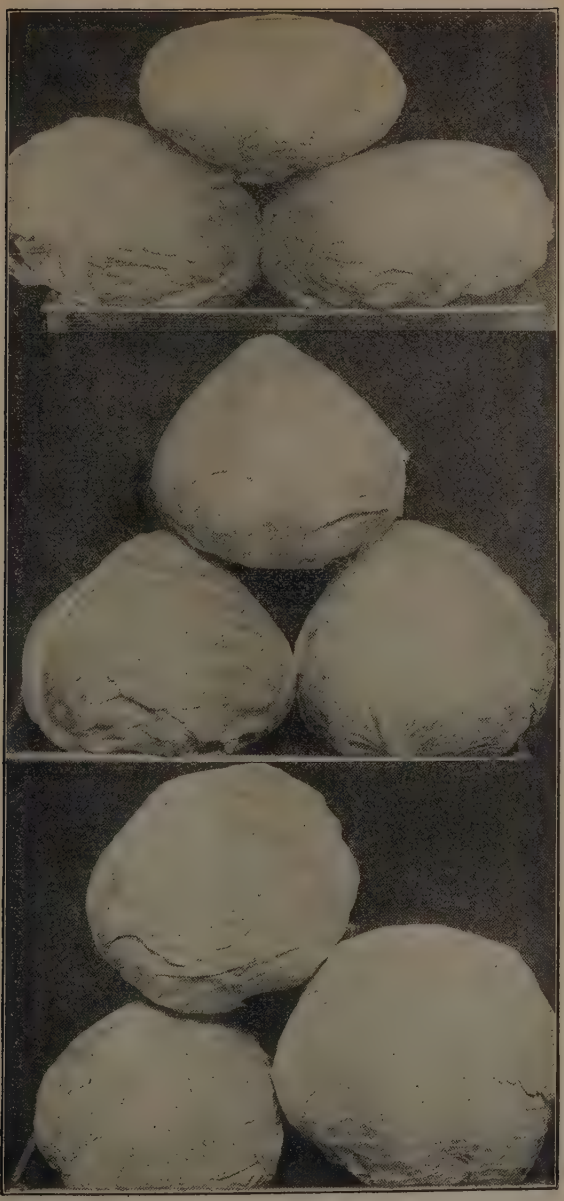

PLATE II.—Cross Cabbage.—Upper and middle figures, reverted to Flat Dutch and Winningstadt; lower figure, true type of Cross.

HINTS FOR GARDENING.

Colorado ranchmen have the reputation of not liking the so-called intensive employment. A trace of the old horse-back farming is still to be found in the ideas of most Colorado farmers. For this reason few farmers take kindly to the hoe. Methods in gardening have improved the same as methods in all other branches of agriculture. It used to be thought that onions, strawberries, etc., should be grown in a so-called bed; a little space of ground ten feet wide by twenty feet long. It is found to be much more economical of time and labor if all garden vegetables are treated in more or less the same way as our field crops. The ground should be prepared as for a crop of potatoes or grain. If a garden is to be made with several of the perenniels as rhubarb, horse radish, asparagus, etc., it should be planned so these may grow all together on one side of the garden. This strip may be left without plowing and will not interfere with the breaking of the rest of the plot. It is well to start the garden next to these plants and run the rows in the same direction. Not less than three feet of space should be left between rows of all garden crops, including onion, lettuce, etc. Where it is desirable to economize space, many of these smaller vegetables may be put in what is known as the double row system. That is, two rows are planted from six to twelve inches apart, then a space of three feet is left for cultivating. There is always a tendency to crowd all vegetables, with the result that the size and quality is frequently sacrificed. The first row should be marked with a line. If a garden drill is to be used the marker will mark the rows ahead so that the line need not be used further. Where a garden drill is not used, it may be desirable to stretch a line and then make a mark by running a bicycle over the ground under the line. If a single wheel is used for this purpose the row will be more or less crooked. Where the bicycle is used, the second wheel corrects the inequalities of the front wheel so the mark will be pretty straight.

Where irrigation is practiced there is always a tendency to use a great deal of water, and to do little cultivating. It is always better to use little water and more cultivation. Thorough frequent cultivation prevents evaporation, and makes plant food available as well as keeping the weeds from getting started. The garden should be cultivated not less than once a week until the plants are too large to get through with a horse. For corn and vine crops as squash, cucumber, etc., it is well to make the space between the rows greater than three feet. An abundant supply of well decomposed stable manure will help to warm the soil and mature the vegetables where the altitude is high and the seasons short.

Bulletin 173 November, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

NOTES ON A DRY LAND ORCHARD

By J. E. PAYNE

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1910

PLATE I.—1. Tree No. 1 just before it was dug. Right side of top dead and left side poorly developed.

NOTES ON A DRY LAND ORCHARD

By J. E. PAYNE

In 1894, a few trees were planted at The Plains Substation at Cheyenne Wells. These consisted of a few each of cherry, plum and apple trees. Some gooseberry plants were set out at the same time. Among the apple trees planted were four Wealthy trees which were headed about five feet high. These were set at the regulation depth—two or three inches deeper than they had been in the nursery row. These Wealthy trees were planted in a row along the east side of the main apple orchard, between the apple orchard and the house yard. It happened that the space west of the trees was kept cultivated up to the time of digging the trees out, while the space east of them had not been cultivated since 1903. By 1910, two of the trees were dead and the two remaining were in bad condition, especially on the east side of each tree.

In 1905, the main orchard was planted in deep-plowed ground. The trees set this year were set in holes dug in dead furrows and about half a barrel of water was put into each hole before planting the trees. It was a very dry time when the trees were planted, but all of them lived. These trees were set only a few inches deeper than they grew in the nursery. All were headed rather low. These trees all grew well. The orchard was kept cultivated so that few weeds grew there. Several trees were killed by rabbits the first winter after they were planted, but only one died from other causes, and it seemed to have been diseased when first set out.

In 1897, the vacancies in the orchard were filled with apple trees which were shipped from an irrigated nursery. All these trees were headed from four to five feet high. As the high-headed trees set in 1894 had grown very little during the three years they had been planted, it was thought best to set these deep enough so that the heads would be the proper height. Deep holes were dug, and they were planted two to two and a half feet deeper than they grew in the nursery. They all grew well and were soon larger than the trees planted in 1894. In the spring of 1910, these deep-set trees were as large as some of the trees set shallow in 1895.

When the orchard was planted, the trees were set so that each tree occupied a space nearly twenty-three and one-half feet square. When the orchard was inspected in the spring of 1910, branches were almost meeting in many places. When the orchard was trimmed, one-third of the trees were marked for cutting out in order to give room for further development. At this time, the trees were from six to twelve inches in diameter at the ground.

This orchard had grown entirely with the water which fell

upon its surface, except such as was brought to it during the first twelve years by a few furrows which carried storm water from about forty acres of prairie. But it had received no water from this source since 1907, when the prairie adjoining was plowed. During three years, it produced quite good crops of apples, and some fruit has been borne every year since 1900.

The Substation orchard is one of the best Dry-Land orchards in eastern Colorado. But, its history shows that the trees have needed extra water at some time during the year every year since they began bearing fruit. If, at this critical time, a barrel of water could have been given to each tree, much more fruit would have been borne and it would have been of better quality.

The foregoing paragraph applies especially to apple trees. The cherry and plum trees produced good crops without extra water nearly every season until they began to suffer from old age. But, it is quite probable that they too would have given larger returns had they received extra water at some time during the year. By 1910, all the plum trees and nearly all the cherry trees were dead. Gooseberries bore well during the years 1896-1900. By that time, they needed thinning and resetting. As this was not done they bore but little fruit during the later years.

Forest trees were planted for windbreaks around the orchard and along the north side of the farm. Honey locust, black locust, Russian mulberry, White elm and Box elder have all done quite well. Russian mulberry bore considerable fruit while left untrimmed. After they were trimmed, they bore sparingly. Some trees bore fruit with fine flavor, while the fruit borne by other trees was insipid, and quite worthless.

ROOT SYSTEMS OF APPLE TREES.

As we were destroying trees, we thought it well to get some facts concerning the development of the root systems. In August, 1910, we dug up four apple trees and examined the root systems, tracing the roots to their ends or until it was impracticable to trace them farther. One tree was a Wealthy which was set shallow in 1894, one was a Wealthy which was set deep in 1897, one was a Mann which was set deep in 1897, and the other was a Ben Davis which was set shallow in 1895.

Tree Number One.—This was one of the Wealthy trees which were set shallow in 1894. It was headed high. It was kept cultivated on all sides until 1903. From 1903 until 1910 the ground on the west side was kept cultivated, while the ground on the east side was not stirred. When dug up, the top of the tree was dead on the east side. Only a few short roots were found on the east side. These grew about five feet horizontally and only one foot deep. But, on the west side four strong roots were traced ten to twelve

feet horizontally where they were still nearly one-half inch in diameter. Judging by other roots which were traced out more completely, these roots were probably fifteen or twenty feet long. None of them grew deeper than fifteen inches. The tree was three inches in diameter. The west side of the tree was alive, but was in bad condition. Plate I, Figure 1 shows the tree as it stood in the ground, and Figure 2 shows a view of the roots.

Tree Number Two.—This was a Wealthy tree which was planted deep in 1897. Its trunk was seven inches in diameter. It was found that the roots grew upward until they came near the surface, and then grew outward or downward according to the soil. Twelve roots of this tree were traced from five to ten feet horizontally from the tree where they were cut off when still one-fourth to one-half inches in diameter. Six of them turned down when three to ten feet from the trunk. These all followed holes which had been made by burrowing animals. Two were traced three feet, one four feet, one five feet, and two five and one-half feet deep. And they were from one-fourth to one-third inches in diameter when cut off. But nearly all the real feeding roots of this tree were in the upper eighteen inches of soil. In few cases during the work of digging out all the trees were roots found going more than three feet deep, excepting those which followed holes. The upper eighteen inches of soil were filled with fibrous roots. Roots from other trees were found interlacing with the outer ends of the roots of all the trees. One view of the roots of this tree is shown in Figures 3 and 4 which shows the tangle of roots starting from the trunk. The subsoil here contained many large lumps in which they were found many white flakes which are supposed to be compounds of lime and magnesia. The roots seemed to have tried to avoid these lumps, going around, over or under them rather than through them. We expected to find many roots above the graft on these deep-planted trees, but none were found on either this tree or the other deep-set tree which was dug out.

Tree Number Three.—Tree number three was a Mann apple tree which was set two and one-fourth feet deep in 1897. It had grown well and its trunk was about seven inches in diameter at the ground. Plate II, Figure 4 shows this tree with roots dug out. The top of this tree spread about eight feet in all directions. The extreme tips of the roots, traced until they were only one-fourth inches in diameter, spread 33 feet. A few of these roots were traced three feet deep. The roots of this tree occupied the upper eighteen inches of soil quite fully in a space 30 feet in diameter. Many of its roots were traced 15 feet from the trunk. The tree had a well-balanced top, and its root system showed a good distribution through the soil on all sides.

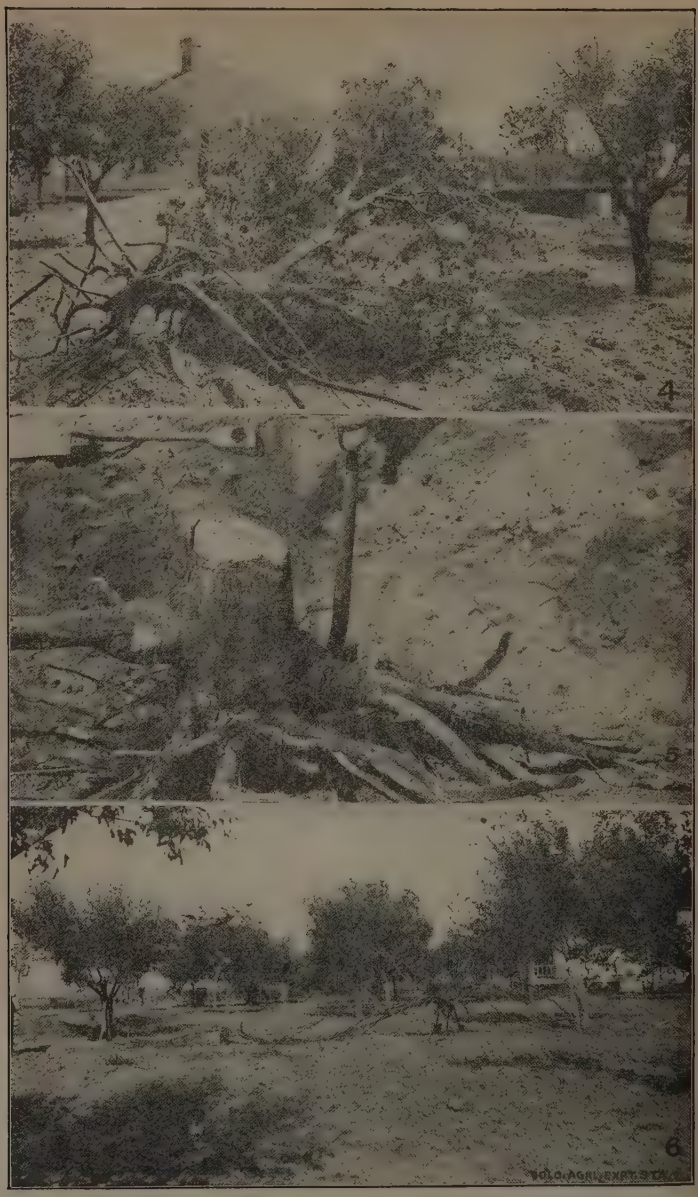

PLATE II—4. Tree No. 3 with part of its roots. The roots spread 33 feet.
5. Stump and large roots of tree No. 4.
6. Roots of tree No. 4 showing roots spread 33 feet.

While digging out this tree, roots of black locust were encountered 30 feet from the nearest black locust tree. In other parts of the orchard, we found roots of black locust 60 feet from the nearest black locust tree.

Tree Number Four.—This was a Ben Davis apple tree which was planted shallow in 1895. It had a well-balanced top, and was eight inches in diameter at the surface of the ground. It had grown well and had borne several crops of fruit. It was healthy when cut down. Some of the roots of this tree were quite large, measuring as much as three inches in diameter where they joined the trunk. This tree stood where it got water from the prairie whenever a heavy dashing rain fell. This made conditions favorable for rooting deeply. One root was traced five feet down, one was traced four feet down and several were traced three feet down. But, the most of the feeding roots remained in the upper eighteen inches of soil. The main roots were found growing most of the distance within one foot of the surface. Fifteen of the large roots were traced distances varying from eight to twenty-six feet. One root was one-half inch thick at 17 feet and was still one-eighth inch thick when broken and lost at 26 feet from the tree. Another was traced 21 feet. The remaining 13 were traced from 8 to 15 feet. These were all cut when one-third to one-half inch thick. The stump with roots attached is shown in Plate II, Figure 2.

In digging out this tree, a Russian mulberry root was found which was traced 50 feet from the nearest mulberry tree. This accounts for the stunted appearance of some apple trees which were planted close to Russian mulberry trees.

CONCLUSIONS.

1. Trees used for windbreaks for orchards under dry-farming conditions are expensive unless the trees of the windbreak group are planted far enough from the fruit trees so that the roots of the windbreak group will not compete with the fruit trees for moisture. The root development of the Russian mulberry and black locust found at The Plains Substation indicate that the windbreak group should be planted 100 feet from the fruit trees.

2. Roots of apple trees do not feed deeply here. If the ground about the ones dug up had been plowed twelve inches deep nearly all the large roots would have been broken.

3. The roots of these trees grew deeper when the soil was wet below the normal depth.

4. Deep planting of trees did not decrease the rate of growth. Neither did it alter materially the position of the feeding roots.

5. The Dry-Land orchard is not considered as a commercial proposition, but it will pay every settler to plant a few well-selected trees and take extra care of them. Nearly all settlers plant more trees than they find time to care for, so they lose all.

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Adobe as a Building Material for the Plains

BY

J. W. ADAMS

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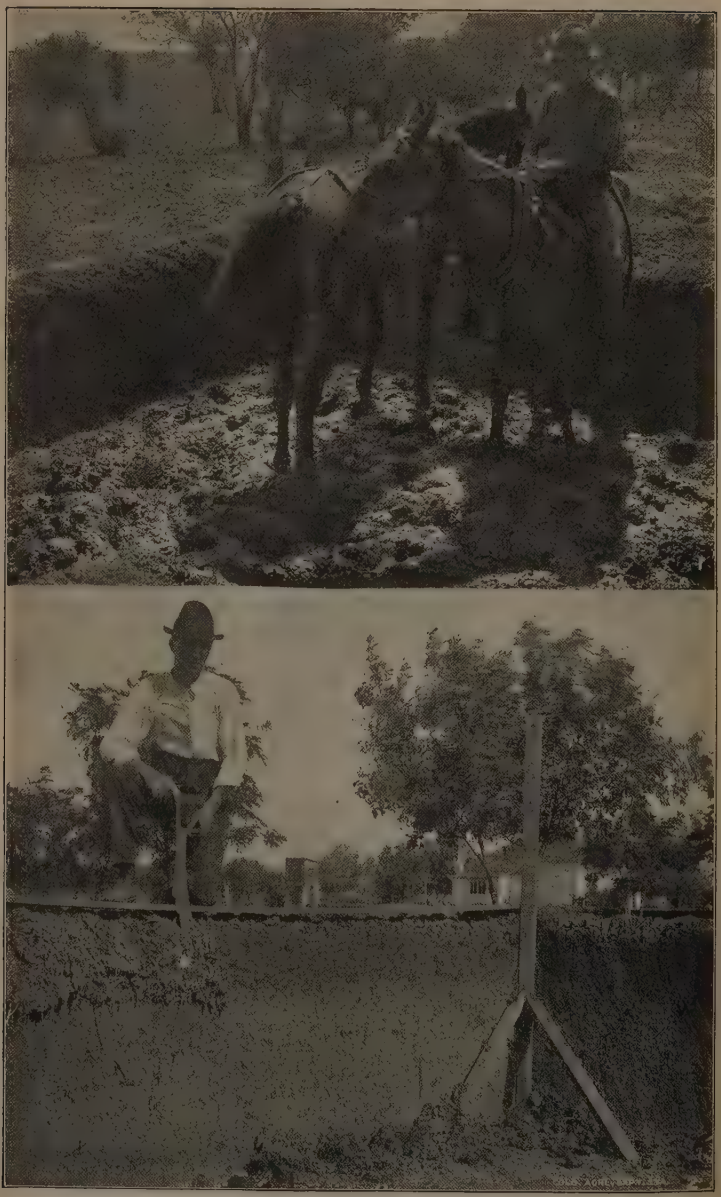
1910



ADOBE AS A BUILDING MATERIAL FOR THE PLAINS.

By J. W. Adams, Superintendent of Plains Sub-Station

To the settlers of the plains, the subject of building material is of great importance. Comfort, cheapness, durability, and neatness of appearance are the elements considered in selecting building material for the homestead.

In this connection, we should like to call the attention of the settlers of the plains to the adobe buildings, or "Dobeys," as they are commonly called. These should not be confounded with the sod buildings. I do not wish to cast any reflections upon the "Soddy." It has served, and is still serving a good purpose as a cheap, comfortable house; but, at best, it is only a makeshift until the owner can build better. The "Soddy" is always settling and cracking the plaster, thus annoying the the housewife. The sod wall is an ideal harbor for mice and rats, and it is usually short-lived.

Not so with the adobe building. An adobe house, properly built, will cost no more than a sod house and yet be as permanent, attractive and comfortable as it is possible to build a house. They do not settle after they are dry. Mice do not work in them if they are protected at the foundation. They are superior to concrete or cement block houses in that they are non-conductors of heat and cold. They never sweat or become frosty on the inside, and rain does not wet the walls through as it does in many concrete houses. The labor required to build an adobe house is no more than that required to build a similar house of sod or concrete.

At the Plains Sub-station, at Cheyenne Wells, we built during the summer of 1910 three adobe buildings which have attracted so much attention and favorable comment that we have decided to publish this bulletin describing these buildings, giving cost of material, time required to build them, and describing the process of building so that any person desiring to build such buildings may do so.

We erected these buildings on concrete foundations eight inches high. This is not necessary, if one is always careful to keep the buildings banked up to prevent water settling around them. The concrete foundation is desirable, however, as a protection against mice and rats. These foundations were very cheap, as we used old cement blocks from a burned building to mix with the concrete. If rock of any kind is available the foundations need not cost much.

In planning a building of this kind, we should consider the kind of roof to be used and make the dimensions such that it may be covered with the least possible waste of material. The dimensions being decided upon, stake out the foundation carefully. If concrete foundation

is to be used it will be necessary to make forms for the foundation. Then set good straight posts in each corner and at intervals of 14 or 16 feet on the inside of the wall. Line and plumb these posts very carefully. If desirable, short stakes may be used instead of posts until the walls get above the stakes, then these may be replaced by posts as high as the walls are to be. Good, straight 2x4 posts are all right. The stakes being lined and plumbed carefully, you are ready to begin the wall.

Now, take your sod plow, select a patch of prairie where the grass is thick and tall—if possible, (avoid sandy soil) and plow a thin sod. You may plow enough at one time for the entire building, if desired. Select a place for mixing the adobe near your water supply, if possible. With small buildings, it may be desirable to mix the adobe in the center of the building, but it will not pay unless your building is so located that you cannot drive around it. Haul your sod and spread it in a circle not to exceed twelve to fourteen feet in diameter. Make the pile about eight inches deep. Now, throw water on this pile until you think you have enough to wet the whole pile thoroughly. Then, get on a horse and lead one or two others (see cut) and make the horses tramp around and around, turning very short. If they are allowed to go in a larger circle they will avoid stepping on the higher places. After you have tramped a few rounds, you will discover dry places in the pile. Throw more water on these places, and continue tramping and throwing on water until the whole mass is mucky. The pile will have a tendency to spread out and some places will be sloppy while others are not wet enough. Then, lead your horses out and take a manure fork (a six-tined fork is best) and throw the outer edges of the mass toward the center, taking care to throw the drier parts to the wet places and vice versa. Tramp again, adding water if needed. It is usually best to throw the edges in the second time in order to get the mass evenly mucked.

If you have been unable to get sod with plenty of grass and roots to form a fiber in the mud you should add a small amount of straw, hay or trash of some kind. Spread it over the mass after it is mixed as above described and tramp again until the straw is all tramped into the mud. When the mass is thoroughly wet and thoroughly mucked, and of such a consistency that it can be handled with a manure fork it is ready to be put into the wall. Throw this on a wagon or sled, discarding any chunks that have not been mucked, draw it alongside the wall and place it in the wall with a fork. Drop it into the wall with sufficient force to make it settle together solid, leaving no holes or spaces. Make as thick a layer as you can without its spreading out too wide. Let it spread over the edge of the wall an inch or two on each side. Be sure that the mud comes out to the edge of the wall at all

places, otherwise there will be holes, or flaws, in the wall when trimmed As soon as you have made one layer around the wall, if the weather is hot and dry, you may be able to start around again placing a layer on top of the first, being careful to make the mud fit down on the first clear out to the edge of the wall to prevent flaws. When you have a layer about 12 inches thick let it stand until it is firm but not dry. Select a board with straight edges fourteen to sixteen feet long and as wide as the thickness of the wall. It the wall is to be more than twelve inches thick, two boards of the proper width may be cleated together to make the required width. Lay the board on top of the wall with one edge against the posts, get upon the board and trim straight down each edge of the board with a hay knife (See illustration). When the walls are trimmed all around in this maner they are ready for another layer of mud. Continue until the walls are the desired height. Never allow a layer to become hard before it is trimmed or you will have a hard job.

The rapidity with which this work may be pushed depends upon the weather. If the weather is hot and dry, you may be able to make an average of six inches per day from start to finish. Some days you may put a foot and then let it rest a day or two. If the weather is cool or damp the work will go correspondingly slower. In early spring or late fall, the work is very slow, and one should not attempt to build adobe in winter.

Keep watch of your walls. If they are not drying rapidly, you had better lay off a day and allow the walls to dry. It is a very good plan to build two or theree feet and then let it stand a week or so and then build two or three feet more and so on until the wall is done.

The frames for doors and windows may be put in place and the mud built to them. But, a better way is to trim the openings for doors and windows, and fit frames into the openings as soon as the walls are as high as the frames are to be. These frames should be of two-inch stuff. The top of the frame should be as wide as the thickness of the wall and should extend into the wall a little. When the frames are in place you may build over them with the adobe. The walls will shrink in drying and draw away from the frames a little, leaving a crack. These cracks may be plastered up with a trowel.

If the roof is to be of shingles or iron, it will be necessary to anchor the plates to the wall to prevent the roof blowing off. This may be done by putting fourteen-inch bolts through short pieces of two-by-four and planting them in the walls as you build so the top of the bolt will just reach through the plate. If adobe or sod roof is to be used, the weight will be sufficient to prevent blowing off. The roof should be leak-proof to prevent water running down the walls and softening them.

PLATE II.—3. Building the wall. 4. Cow barn 26x60 feet inside. 5. Poultry house.

We built at the Station this year a cow barn, a hen-house and a moke house, or store room. The cow barn is 26 feet wide and 60 eet long, inside. The walls are twelve inches thick and seven feet igh, with concrete foundation eight inches high. On the south side, he walls were built only four feet with adobe. The remaining three eet is framed with two-by-six lumber and enclosed with muslin cur-ains. (See illustration. The picture was taken before the curtains and oors were on.) These curtains furnish light and ventilation with-ut draft. The roof is of corrugated iron. The rafters are 2x4x16 aced two feet apart, with cripples at the splice in the iron and one the middle of the iron to prevent sagging. The iron is nailed to on at edges, lapping two inches. The rafters are supported by two rows f 4x4 posts—four feet on each side of the center of the building. t the top of these posts, a 2x6 is spiked for the rafters to rest upon. The iron was painted on the under side and in the splices before it as laid. The upper side was painted after it was laid. The gable nds are boarded up with shiplap. Eighteen feet of the west end is artitioned off for feed, and a large door is left in the gable end hrough which to throw feed. On the south, there are two doors. One three feet wide, hung on hinges, and the other six feet wide, hung on ubular track.

We have two rows of swinging steel stanchions supported by the me posts which support the roof, leaving a nice feed alley between he mangers. Twenty-eight feet of the barn has concrete floor with itters and troughs of concrete.

The cost of the building in cash and labor is shown below:

Cement in foundation, $6.60, floor $23.40		$ 30.00
Lumber for entire building		232.74
Total		$ 262.74
Man labor	601 hours	
Team labor	142 hours	

POULTRY HOUSE.

The poultry house is 14x20 feet, inside. The end walls are 12 ches thick and the side walls are 10 inches thick. The walls are six et six inches high at the eves, and nine feet high at the gable. The outh wall is only three feet six inches of adobe, the other three feet eing framed and curtained in winter, and screened in summer.

The roof is made by laying joists, of 2x6 lengthwise about three et apart. The ends are toenailed to blocks laid in the adobe. The iddles are spliced and rest on posts. Shiplap is laid on the joists, nd a kind of tar paper or rubberoid is laid on the shiplap. This is

covered with adobe such as is used in the wall. The adobe protects the paper and adds weight and warmth to the roof.

The house is plastered on the inside with a mortar made of sand and common soil. We used as much sand as could be put in without making the plaster crumble. It has not cracked at all and is as hard and smooth as lime plaster, but it will not stand wetting. This makes as good a poultry house as it is possible to make. It is neat, warm and light. The muslin front furnishes light and ventilation without draft.

The cost of building is shown below:

Cement $1.80, lumber, nails, etc. $29.44		$ 31.24
Man labor	114 hours	
Team labor	42 hours	

STORE ROOM, OR SMOKE HOUSE.

The smoke house is 14x14 inside. The side walls are 10 inches thick and the end walls 12 inches thick. The height is seven feet at the eaves and nine feet at the gabels. It is built on the same plan as the poultry house, except that we have two four-light single-sash windows instead of curtains. It is plastered with cement instead of earth. We have four 2x4 pieces crosswise just beneath the plates. Boards can be laid on these to form a small attic in which to store things.

The cost is as follows:

Cement $3.00, lumber, nails and paper $21.87		$ 24.87
Man labor	131 hours	
Team labor	42 hours	

The question will probably be asked why it took so much longer to lay up the walls of the smoke house than to lay the walls of the poultry house when there is really a little more wall in the latter. This can be easily explained. The men who laid the poultry house walls had continuous work and the advantage of experience and knew just how to go at it. But, the smoke house was built at odd times, and by severel different men, each having to learn his trade

THINGS TO BE EMPHASIZED.

1. Line your posts and plumb them carefully, and your walls are bound to be straight and plumb.
2. Be sure to make good joints between layers.
3. Never allow adobe to get hard before trimming.
4. Never allow dry or untramped chunks of sod to enter the wall.
5. Never allow water to settle against the walls.

Cement and block off on the outside and you have a very attractive and durable house.

Bulletin 175 November, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

The Potato Industry of Colorado

By C L. FITCH and E. R. BENNETT

POTATO INSECTS

By S. ARTHUR JOHNSON

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1910

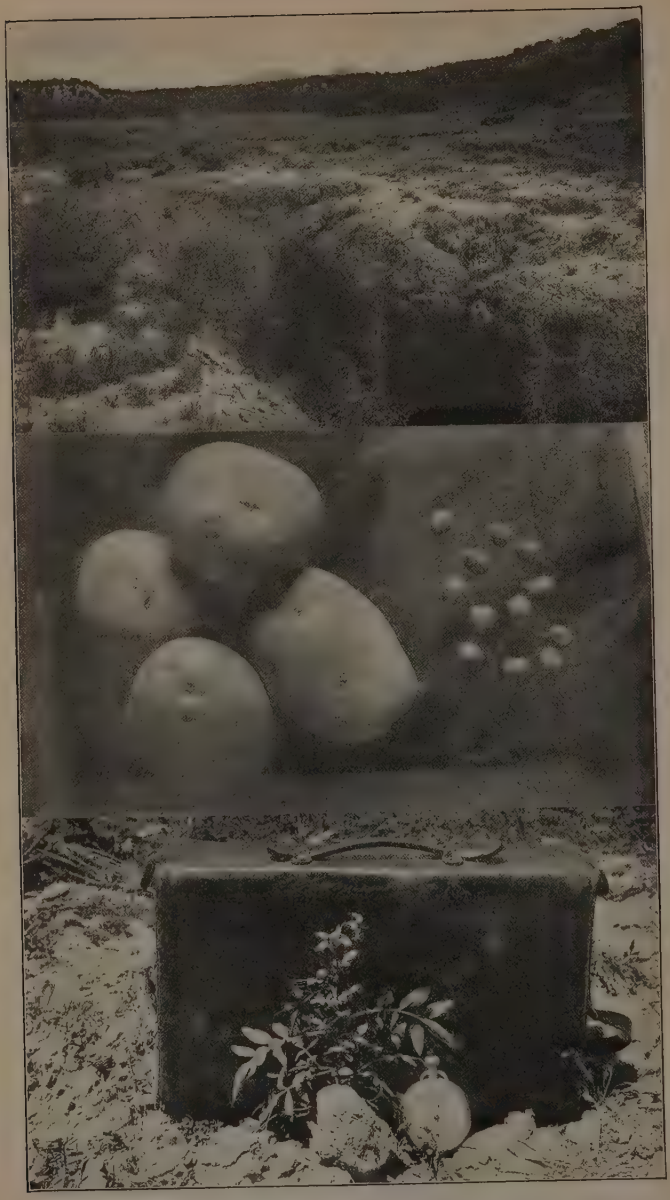


PLATE II.—THE COLORADO WILD POTATO (Solanum Jamesii)
1.—Habitat at Tiffany, near Durango. 2.—Size of Tuber as compared with Rurals
3.—A wild plant with two blossoms and seed ball

THE POTATO INDUSTRY OF COLORADO

By C. L. FITCH and E. R. BENNETT

PREFACE.

When the cattlemen first established their home ranches in our mountain valleys and in the creek bottoms on the plains, they found the dark, sandy, alluvial loams good potato soil, rich with the wash and willow leaves of ages, and large returns were secured for years on these soils. The introduction of alfalfa from Utah and California made the bench lands even more productive, and when farmers learned how to break and handle the alfalfa sod, it proved the greatest factor in the extension of potato growing and of irrigation development generally. The total output was doubled from the same areas in a few years' time and the possibilities of profit woke up the state.

A little later the fine shape and wonderful quality of mountain potatoes became known outside the mining and lumber camps, and railroads saw the possibilities of agricultural freight, and farm development.

Somewhat later the newer districts made so many demands upon the Agricultural College for advice and instruction that the Board of Agriculture secured a potato specialist to work for the growing industry. The attention of growers and of business men generally was called to the geographical position of Colorado with reference to the production and consumption of potatoes and the specialist went up and down through the mountains as an instructor and adviser to the newer potato districts. In connection with the Rio Grande Railroad and the department of Farmers' Institutes, Professor Cottrell took expert potato growers to the newer mountain districts, and later three special institute trains were run by the railroad and the college that were of great use, both to the railroad and to the people along its line.

In 1895 Colorado put in 37,000 acres of potatoes and produced three and one-half million bushels and ranked as the twentieth state in the Union in total potato production. Next year she was twenty-second. In 1900 she was twenty-third. In 1902 Colorado rose suddenly to sixteenth place in the Union. In 1903 she was tenth, and since that time she has held about that position. In 1906 her crop fell to the sixteenth, and in 1909 it rose to the ninth state. This year the August freeze at Greeley has lowered her position again to the twelfth place. The acreage in 1910 was 64,000.

In money value per year her crop in fifteen years has grown from a little over a million dollars to an average, since 1903, of more than four millions of dollars, with the highest total in 1909

of $5,928,000. The production in bushels has risen from three and one-half millions to an average of between seven and eight, with the high point in 1909 of 10,400,000.

As to the future, more acres will be put in to potatoes, and great increases in production are to come from better methods. Better understanding of seed potatoes and the laws of productiveness are to be a big factor. Improved strains and improved varieties will count a great deal, and we are beginning the work of developing such strains and varieties.

It is calculated that improvements in varieties and seed stocks can workably affect a minimum increase in quality and value of five per cent., and associated with it will be an additional yield of at least as large an amount. If we figure only ten per cent. on a six million dollar crop, and another ten per cent. in possible betterments of methods, the economic prize to the state is well worth reaching out after. Colorado has been ambitious for her potato industry and its expansion, and liberal in her provision, that no industry be better served, and that the experience of all be gathered and made available to all, to the end that potato growing shall be nowhere on a higher plane of intelligence, service or profit.

With this brief general glimpse of the potato industry of Colorado, and its relations with the college, we will plunge into a detailed account of potato growing and its problems, designed for the use of Colorado growers, of those interested in the crop commercially, and of high schools in potato districts. To it is appended a report of field work in 1910.

INTRODUCTION.

THE POTATO CROP.

More weight of food is produced by potatoes than by any other crop of the world. In number of bushels the potato far exceeds any of the great cereal crops of the world; wheat or corn or rice of the Orient are far behind it in total production.

Per Capita Consumption.—While the potato is universally used among American people, the consumption per capita is notably less than in Europe. According to the statistics of the Department of Agriculture, the crop of the United States is not far either way from 300,000,000 bushels per year, or 3½ bushels per capita. Germany, a country that is a little more than twice as large as Colorado, produces 1,600,000,000 bushels, or from five to six times as many as the whole United States. The people of Germany, as well as the people of Ireland, in place of using 3½ bushels of potatoes per year, consume twenty-five bushels per capita.

Where Grown.—By far the larger part of the potatoes of the United States is grown in a few of the *northern* states. In fact Maine, New York, Pennsylvania, Michigan, Wisconsin, and Minnesota produced half of the immense crop of 1909.

While Colorado is the 10th or 11th state in production of potatoes, she is one of the leaders in the investigation and promotion of the industry. A little study of potato prices and possibilities of potato growing will show why Colorado is one of the leaders in this work.

TABLE 1.—Average Yield of Potatoes per Acre, in bushels.
(From U. S. Dept. of Agriculture, Yearbook.)

Year:	1904	1905	1906	1907	1908	1909	Average
Nebraska	120	93	87	73	78	78	88
Wisconsin	126	68	97	91	80	102	94
Michigan	121	67	95	90	72	105	91
Iowa	136	80	95	85	80	89	94
Minnesota	102	87	92	101	76	115	95
New York	93	70	105	98	82	120	94
Colorado	159	160	125	150	125	160	146

TABLE 2.—Average Farm Value of Potatoes per Acre, on Dec. 1.
(From U. S. Dept. of Agriculture, Yearbook.)

Year:	1904	1905	1906	1907	1908	1909	Average
Michigan	$35.09	$37.52	$32.36	$40.50	$41.76	$36.75	$37.33
Minnesota	29.58	41.00	34.04	41.41	42.46	42.24	38.45
Wisconsin	35.28	42.16	29.10	40.95	48.00	38.39	38.96
Nebraska	31.20	34.41	45.25	51.10	42.90	46.80	41.94
Iowa	38.08	39.20	40.85	46.75	48.00	48.95	43.63
New York	50.22	49.00	51.45	55.86	61.50	60.00	54.67
Colorado	58.83	91.20	56.25	99.00	75.00	91.20	78.58

*These states are direct competitors of Colorado, with the exception of New York, whose great acreage gives the state a large influence in the potato market of the United States. Maine alone, among the great potato producing states, exceeds Colorado in production per acre, but Maine's geographical position and large costs of production are such as to exert little influence on the Colorado potato industry.

Colorado Yields Compared With Other States.—One half more potatoes per acre are shown by Table 1, to be produced annually in Colorado than in any of the great potato states mentioned. These averages cover the whole state, not only the irrigated parts but a large area in eastern Colorado that does not, and never can be expected to produce the highest yields.

Money Value Per Acre.—Yields per acre do not necessarily mean high money values. Table 2 shows that Colorado not only produces a high average yield of potatoes, but that the value per acre is also more than in any of the states mentioned.

Net Profit.—Again, yields per acre, or values per acre, do not always mean net gains. The cost of growing must be taken into consideration as well as the gross income. In Colorado, by far the greater proportion of the crop is grown by irrigation and it may be claimed that this increases the cost. This is true, but the cost is much more than offset by the fact that practically no fertilizer for growing this crop in Colorado is needed, and that in a large part of the state no spraying is done for either fungus diseases or insect pests. In fact, these two items alone, in many cases, cost more per acre in some of the great potato producing states than the total cost of production in Colorado.

Native Home of the Potato.—While the potato is a native of the tropics, its habitat is at a high altitude. By far the greater part of the potatoes grown in the United States are produced along the northern border and few are produced in the south.

Potato Prices, North and South.—Last year the price of potatoes in Wisconsin, Michigan, New York and other northern states was less than fifty cents per bushel when potatoes were from $1.00 to $1.10 per bushel in South Carolina, Georgia, Florida and Texas.

Colorado's Favored Position.—Colorado is practically half way between the producing and consuming regions. This gives the growers a great advantage over their competitors in these high priced markets. The northern states have the cool climate which adapts them to potato growing, because of their high latitude. Colorado, because of its high altitude, has practically the same summer climate as far as temperature goes.

Dryness and Sunshine.—The northern states have, with their cool climate, a tendency toward humidity and cloudiness that Colorado does not have, and as sunshine is a most essential thing in plant growth, Colorado has a considerable advantage in this respect.

OUR TERRITORY AND ADVANTAGES SUMMARIZED.

Northeastern Colorado.—Until the present time, the major part of the potato production of the state is confined to the Greeley district, which embraces approximately 250,000 acres and will be nearly doubled by ditches under construction. East along the Platte, including the country about Fort Morgan, Sterling and Julesburg, potatoes are being grown more than formerly, and the dry land growers of these regions are taking greater interest in this crop.

The San Luis Valley.—This valley includes an area of 3,100,000 acres of land, which is largely adapted to potato growing and has untold possibilities. In fact if one-tenth of the area of the San Luis Valley were to be planted in potatoes, and should produce 10,000 pounds per acre (which is not a large yield for this district), the valley would produce one-fifth of the present potato crop of the United States.

The Grand, Eagle, and Crystal River Regions, known as the Carbondale and Eagle district, contain many thousand acres of land admirably adapted to potato growing but not yet fully developed.

The Uncompahgre and North Fork Valleys comprise more than one hundred thousand acres of land, the most of which is adapted to the growth of this plant.

Archuleta, Montezuma, Dolores, La Plata, and San Miguel Counties, in the southwestern part of the State, have large areas that are well adapted to this crop but not yet developed to any great extent owing to a lack of direct transportation.

Rio Blanco, Routt and Grand Counties have remained largely undeveloped for the same reason as the last section, although they have many thousand acres as well adapted to the growth of this crop as those districts that have become famous.

A Summary of Advantages: Colorado climate is ideal for potato production, eighty-five per cent. of the days in the year being fair.

Colorado soils need no fertilizer for the growing of this crop out side of the established rotations.

Colorado's geographical position gives a big saving of time and freight in reaching the high priced markets of the United States.

Few of the many potato diseases trouble Colorado growers.

Colorado's production per acre, including a large per cent. of unirrigated lands, is much greater than that of the great potato producing states with which we compete, and the value of the crop per acre is about double that of those states.

The money received for Colorado potatoes is largely net gain to the State as very little money is sent out for fertilizers, etc.

The potato crop at present brings to the growers approximately $6,000,000 a year. Colorado has undeveloped lands enough to make the total output several times what it is at present.

THE BOTANY OF THE POTATO.

Solanum Tuberosum, is the botanical name for the common potato of commerce. It is closely related to the tobacco and tomato and to the nightshade, the egg-plant and the buffalo-bur. Other species of tuber-bearing Solanums have been domesticated in the hope of finding a potato equally as good as *tuberosum,* and one that would be more resistant to fungus diseases. Among these are *Commersonii, Maglia,* and *Jamesii,* the last being a native of the mountains of southwestern Colorado. None of these species have ever become valuable as a source of human food.

What Is a Potato?—Botanically, the potato is a tuber or enlargement in a stem or branch, normally under ground, but sometimes above, even in upper branches when disease or accident has interfered with the formation of tubers below ground. Not infrequently growers speak of the potato as a root, or growth from the root. The tuber has no connection with the root system of the plant. This structure of the potato may be best observed by examining the the plant about the time the blossoms are forming. If the plant is carefully dug, the small stems will be observed growing from the main stem of the potato above the seed piece from which the plant came.

Tuber Stems Vary greatly in length with the varieties. The stem of the Pearl is short, and the tubers are set close in around the old seed piece. The stems and tubers of a Rural New Yorker go more deeply into the soil. The Peachblow has not only a long underground stem, but often the stem continues through the first tuber, so as to have two or even three tubers on the same stem.

Potatoes from Seed.—While the plant is usually reproduced by cuttings of the tuber, it may be reproduced from true seed, as it undoubtedly is propagated in part under wild conditions. Many of our best varieties of potatoes, however, never produce seed balls, nor even perfect blossoms. (For a discussion of this point see Bulletin No. 176.)

The Function and Development of the Tuber.—The plant food, elaborated by the plant during the summer, is deposited in the tuber for the use of coming generations of plants, and a very large part of this food is deposited during the last weeks of the plants' growth.*

*For an explanation of tuber structure see Quality of Potatoes herein.

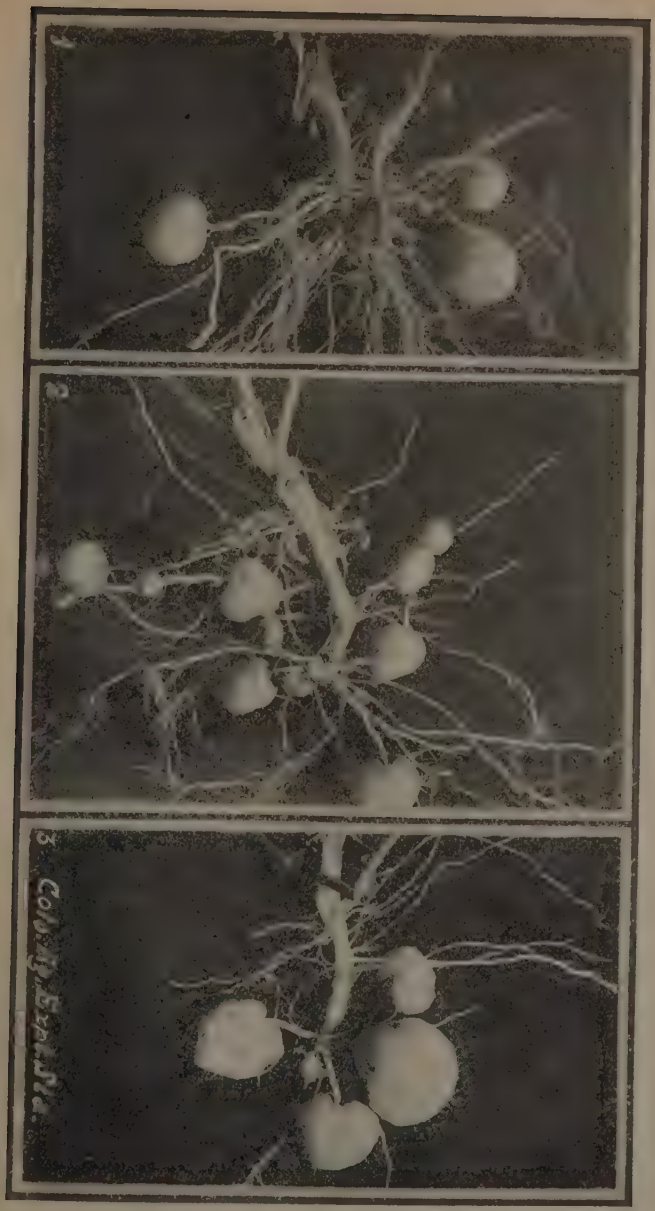


PLATE III.—HABITS OF GROWTH

1. Rural. 2. Peachblow. 3. Pearl

It has been found in several experimnets that where the ground and plants are in good condition when the tubers have set, that a fair yield of tubers may be obtained, even though the top soil be dry so that little more plant food could be taken from the soil. This is an important point, in our irrigated districts, as we believe that entirely too much water is ordinarily given after the tuber-forming season of growth. We believe that where the soil is in fairly moist condition at the bottom of the hills when the tubers are one-third grown, that the yield will be practically as great if no more water is given, as if another thorough irrigation is applied. Those plants that die back to the ground each winter as the asparagus, rhubarb and lily take care of the plant food by storing it in the underground parts. This is also true of the potato except that the food is stored in a different part of the plant. If the potato stem or leaf be examined during the latter part of the season, considerable quantities of starch will be found in the tissue. After the tuber begins to form, this starch is rapidly transferred to the tubers. In a field at Greeley in 1908 four plots were staked out by us, each of which contained 1/100 of an acre and were as nearly uniform as possible. The first of these plots was dug August 25. At this time a few of the tubers had reached the size of six or seven ounces. The plants were in good condition of growth and the soil moderately moist. The tubers dug weighed seventy pounds, or seven thousand pounds per acre. Nine days later the second plot was dug. In the meantime the tubers had very materially increased in size so that many of them weighed more than one pound. The total weight of the plot was one hundred fifty pounds or 15,000 pounds per acre. One week later the next plot was dug, which gave 170 pounds, or 17,000 pounds per acre. If the first plot had been dug two or three days earlier and the second plot two or three days later it would have been found that by far the larger part of the total tuber growth was made in two weeks.

POTATOES MIXED IN THE HILL.

The Botanist and the Farmer.—The botanist knows that potatoes cross or mix in the seed, and not in the tuber. The grower knows, as an actual fact, that he finds different colors and kinds of potatoes in the same hill from the same seed piece, and he often vows that the botanist is a theorist.

Both Are Right.—There is no occasion for bad blood on the subject. There is the highest authority that both are right. Just as Albinos are born in human families, or as peaches and apples sometimes have limbs whose fruit varies from that of the rest of the tree, so white potatoes come in purple hills, or purple in white hills, or round ones among long tubers, by natural variation, or coming up of diverse inheritance.

The Origin of Many Varieties.—By bud variation White Pearl potatoes came from Blue Victors,* White Ohios from Red Early Ohios, and Red Peachblows from the old spotted Jersey Peachblow. Thus, of the above Colorado standard varieties, three came "mixed in the hill," although they did not mix there, and only our Rural came to be what it is without this factor. The Rural came direct from the seed ball and so did the regular Early Ohio—the latter a cross between the Hebron and the Peachblow—"mixed," or crossed in the seed ball.

HISTORY OF THE POTATO IN COMMERCE.

The Potato Was Discovered in 1532 by the expedition of Pizarro near Quito in Peru, where it was cultivated at an elevation, they thought, greater than the line of eternal snow in Europe, and was found growing wild still higher above the tilled lands of the Incas.

Spain, Italy, and France soon saw specimens of the tubers, first as botanical curiosities and then as a possible source of food for peasants. In 1586 the plant was brought to the attention of Queen Elizabeth of England. As late as 1719 the potato was not listed in a garden manual in England which purported to be complete. Somewhat over 200 years ago, interest had been shown by English landlords in the growing of potatoes for food for their Irish tenantry and the crop soon thereafter became important throughout Europe.

Germany, Russia, Austria, and France, in the order named, lead the world in the total production of potatoes. Their use as food for stock, as a source of alcohol for mechanical and household purposes, and as a source of starch for cloth makers and laundries, is now a great factor in the consumption of the potato.

Why Grown.—Climate and the cheapness of the potato as a food (with no process of manufacture needed) among people where cheapness is desired or imperative, together with the small knowledge required for moderate success with the crop, have been the chief factors in the extensions of potato culture. The appreciation of good potatoes as a staple food is a later factor.

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*In a field of White Pearls in 1908 we found in different hills two potatoes which had small purple spots covering eyes. These tubers were planted that winter in the college greenhouse, the purple and white eyes separately. The potatoes grown from these pieces came true in color to the color of the eyes planted, and they were planted in the field at Greeley in 1909, again coming true in color except for some white streaks on the purple variety. This stock was planted in 1910 at Del Norte and again came true each to its color. These are the "White-Eye Pearls," and "Purple-Eye Pearls," noted in the Del Norte Tables.

Corn, Tobacco and Tomatoes have remained to a great degree American crops, the tomato having been the last to enter use on a commercial scale, and that almost entirely in America. Cotton came to us and we lead the world in its production. It has been the reverse with the potato. South America, its home, produces less in total than Colorado, and the potato crop of the United States is insignificant as compared with that of Europe.

The Potato as Freight is important, because it is better economy to grow it in the north, or in the high altitude districts, and transport it south, than to grow it in the uncongenial climate of the south. The weight of the potato crop of the world is nearly half more than the leading grains—wheat or corn—and nearly three times the weight of the world's rice crop. The average crop, in tons per acre, of potatos in Colorado, is about six times that of grain. Fully as large a per cent. of the potato crop is shipped by rail as of wheat or corn, and potatoes pay a higher freight rate.

QUALITY IN POTATOES.

Table Quality in potatoes is an important factor in the development of the industry in the United States. All but a very small per cent. of the potatoes grown in this country are used for human food. When the quality is high the amount consumed per capita is considerably more than in years when the quality is low. Attention on the part of the growers to producing smooth, white fleshed, mealy tubers will increase the per capita rate of consumption.

What Constitutes Quality.—From the American standpoint, the popularity of the potato as a food depends for the most part upon its starch content, because in the United States the consumer demands a mealy potato. In continental Europe, France in particular, a soggy potato is preferred. The amounts of starch and other ingredients vary with the variety and also with the conditions under which the potatoes grow. C. F. Langworthy in the Yearbook of Agriculture gives the average chemical analysis as follows: "The edible portion of a potato is 78.3% water, 2.2% protein, .1% fat, 18.4% carbohydrates (principally starch), 1% ash or mineral matter."

A Thin Cross Section of a potato held to the light will show that the tissue is composed of several different layers or areas. The outside *skin* corresponds to the bark of the stem; inside the bark is the sap wood or vascular tissue which in the potato is known as the *cortical layer*. This is readily distinguished as a layer from one-eighth to one-half inch thick just under the skin and is bounded by a dark line of *fibro-vascular* tissue. Inside this line is another area that is ordinarily of about the same density as the cortical, known

as the *external medullary* area. This corresponds to the heart wood of the stem. Inside this area is an irregular tract of much more transparent tissue. This is called the *internal medullary* area and corresponds to the pith wood of the stem.

Proportions of Each Layer.—The French chemists, Coudon and Bussard, give these different areas that make up the body of the potato in the following percentages, as average, by weight:

Envelope or skin 8.79%
Cortical layer 36.19%
External medullary area 34.17%
Internal medullary area 14.96%

Chemical Composition of Each Layer.—The following table taken from their analysis shows the relative amounts of starch and nitrogenous matter in these different areas:

	Starch per cent.	Nitrogenous matter	Water per cent.
Cortical layer and skin.....	19.42	1.99	74.79
External medullary area	16.29	2.14	77.44
Internal medullary area.....	11.70	2.31	82.16

Thick Cortical Best.—As will be seen the cortical layer is richer in starch than the outer medullary and both of these are very much richer than the pith or inner medullary area. Consequently the potato with the thickest cortical layer contains the greatest amount of starch. It is also true in this table that the per cent. of water and total nitrogenous matter increases from the outside to the center of the potato. This analysis was made from three European varieties which were bred for nitrogen content rather than for starch. Analyses made at the same time, however, show that while the total nitrogen increases from outside to center, the per cent. of proteid nitrogen or that which is digestible, to the total nitrogen decreases from the outside to the center.*

*E. M. East, in a bulletin published by the Illinois Experiment Station, makes the following observations in regard to physical structure and quality in potatoes.

"Microscopic examination of the structure of the potato bears out the chemical analysis of the different zones.

"The cortical layer, below the first few layers of cells which are removed with the skin, shows a markedly larger amount of starch in the cell than does the internal medullary layer. The starch content of the external medullary layer is also greater than that of the internal. The grains of starch in the cortical and external medullary layer besides existing in greater number per cell are generally of larger average size. The paucity of starch in the internal medullary area causes the cells to be only partially filled with the cooked starch and the cell walls are scarcely ever ruptured. In the cortical layer, on the other hand, the amount of starch is such that in the swelling due to cooking, the cells are filled completely and many of them ruptured causing the mealy appearance so much desired by the consumer.

"It is quite evident then that potatoes having so far as possible a homogeneous flesh and containing as large amount as possible of cortical and outer medullary layers in proportion to the inner medullary layer, should be the finest quality."

Where there is a shortage of starch in the cells the cell walls retain their structure and the water contained in the potato is not all taken up by the starch with a result that the potato is soggy, and not mealy.

A Microscopic Examination of different potatoes shows that the starch granules differ in size with the different varieties. In comparing Snowflake with Pearl it is found that while the Snowflake has a large quantity of starch granules the average is much smaller than in the Pearl. The greater number apparently makes up in this case for the size of the granules so that ordinarily comparatively little difference is found in the mealiness of these two varieties when each is properly grown. In general, it may be said that the Snowflake is finer grained when cooked than the Pearl and very much finer than the Peachblow, probably owing to the difference in the size of the starch granules.

The Degree of Ripeness of the tuber has much to do with its chemical constituents. The unripe potato is usually richer in nitrogen but decidedly deficient in starch content. A high starch content does not necessarily mean a good flavored potato. The German potatoes that are grown for alcohol and starch making, are richer in starch than the better varieties that are used for culinary purposes, but are decidedly deficient in flavor.

What Causes Flavor in a potato is not known. There is apparently the same difference in varieties of potatoes in regard to flavor as with fruits, only to a lesser degree. Freedom from disease of any kind, absence from exposure to light, and mechanical texture, are known to be large factors in potato flavor.

Market Standards are largely set by size and appearance of the tubers. It has been found that a tuber weighing from eight to twelve ounces is the most desirable both from the standpoint of economy in handling and cooking and from the standpoint of quality. Very large tubers are apt to be coarse in texture and frequently hollow in the center as the result of the breaking down of the pith cells. This tendency toward being hollow is a varietal characteristic, but all potatoes are more or less subject to it when overgrown. The large potato is also more apt to be deep eyed than the medium sized tuber.

Loss in Paring.—Few people realize the loss of food material in paring the small, rough or deep eyed potato. The following table shows comparative losses from paring different sized tubers:

	Original weight	Pared weight	Loss	Loss %
Smooth	10½ oz.	8⅞ oz.	1⅝ oz.	15%
Smooth	6¼ oz.	5 oz.	1¼ oz.	20%
Smooth	3¾ oz.	2⅞ oz.	⅞ oz.	24%
Rough	7¾ oz.	5¾ oz.	2 oz.	26%*

* In cracked, very rough, or deeply flea-marked potatoes we find a 40% loss in paring often unavoidable; and in extreme cases this loss may run to 75%.

Loss of Food Value.—The loss in weight is not the only serious part of paring away the tuber. As has been shown, the food value of the area of the potato just beneath the skin is much greater than the center of the potato. Where potatoes are particularly rough it will be seen that not only is one-fourth of the weight of the potato removed but considerably more than one-fourth of the real nutriment of the tuber is lost, and that of the best quality.

HOW TO DETERMINE GOOD POTATOES ON THE MARKET.

Color no Guide.—It is not uncommon to hear consumers say they always use certain colored potatoes as they have found them to be better in quality than some other color. So far as has been determined, there is absolutely no correlation between color and quality. Certain markets demand a certain colored potato to the exclusion of all others simply because they have been educated to that color. In fact, if it were desirable to do so, it would be possible by breeding to change the color of nearly any of our potatoes from white to red or the opposite.

The Appearance of the Skin indicates the quality of the potato. When the skin of a given variety is smooth and more or less transparent with what is called a "baby skin," and the potato has a soft spongy appearance, it is usually deficient in starch and is apt to be soggy. This condition is usually the result of immaturity of the tuber. The tuber should have a russeted appearance due to crackled skin; and it is usually considered a mark of good quality when the potato is well covered with lenticels. The degree of russeting differs with varieties but with a given variety the more russeted potatoes are the better in quality.*

The Amount of Irrigation given to the plants has much to do with the quality. It has been found in Colorado that soils that are well drained, and particularly those soils which are newly broken from prairie or sage brush, usually give better quality than older soils that are more retentive of moisture. Where irrigation is stopped early to allow the potato to mature in a dry soil the quality is greatly improved over those that mature in a wet soil.

Proper Irrigation a Help to Quality.—The growth of the tuber may be controlled under irrigation so as to produce the highest

*Gilmore of the Cornell Experiment Station found that with most potatoes those growing close to the surface were not so good quality as those grown deeper in the soil, doubtless because the deep grown tubers set first and had a longer season with greater ripeness. It has been found also that where plants reached a natural maturity before the vines were killed from disease or frost, the tubers were superior in quality to those from plants destroyed previous to this condition.

quality possible, as water may be given as needed, and in Colorado diseases rarely prevent the plant from reaching full maturity before frost. Where early irrigation can be practiced, and tubers can be set early, they reach fuller maturity and finer quality. The naturally dry climate of our State makes it possible in most seasons to mature potatoes in dry soil.

VARIETIES.

Success or failure in potato growing depends most vitally upon selection of the right variety.

The White Pearl.—This variety, known as Peerless in the eastern states, is adapted to more conditions and soils in Colorado than any of the others that have been grown. At least two-thirds of the potatoes grown in Colorado are of this variety. It is a standard at Greeley and in the San Luis Valley and does well on the West Slope and on dry land farms. The Pearl, in season, is neither early nor late. As this potato is the most common one grown in Colorado we shall use it more or less as a standard by which to compare other varieties.

The Rural New Yorker No. 2.—This standard variety, the leading sort in the United States, is ordinarily a little smoother and more uniform in size and shape than the Pearl, and is from a week to ten days later in season. It is somewhat more subject to diseases other than early blight, and is influenced by adverse weather conditions more than the Pearl. In the Uncompahgre district it seems to be even better adapted to the climatic conditions than the Pearl and gives fully as large yields.

The Peachblow, wrongly known as Red or White McClure, is the potato with which Carbondale has made her name as a potato growing district. This potato is fairly uniform in size and quality but seems to be adapted only to the best environment. At Greeley, this variety quickly degenerates and changes its color and characteristics. It is the excellence of Carbondale conditions for potato growing and not any particular variety that has made the region famous.

The Ohio Family, the leading early potatoes of the United States, are characterized by high quality, extreme earliness, low vitality, and moderate or low yields, with a tendency to poor shape. To this family, all much alike, belong the Adriondack, Six Weeks, Acme, and White Ohio.

Other Varieties.—*The Irish Cobbler is a strong competitor of the Ohios, and is already displacing them to some extent in Colorado. The Charles Downing, a close relative of the Snowflake, is of excellent quality and is desirable in some localities for mid sea-

*See **Early Potatoes** for comments on the Cobbler.

son market. In the San Luis Valley, a potato known as Monroe County Prize, has been grown for a long time and is a desirable, long potato. The Russet, grown in the Carbondale district, is a high quality, early, long potato of great promise in our mountains. See *Field Experimentation* for the undesirability of any other sorts than those mentioned here.

SOILS.

What is a Potato Soil.—In a very general way this question may be answered by saying that potato soil is deep sandy loam, with some sort of under drainage. Potato growing in the Greeley district is on soils that range from light sand to heavy clay. The underlying stratum of most of this district is coarse gravel at a depth of from one to several feet. Some of their best lands are deep medium sandy loams underlaid with porous white clay either above gravel or in connection with a good slope.*

The Character of the Subsoil appears to be more important than the character of the surface soil. In fact some of the heavier soils of the district where underlaid by gravel at two to five feet, are among the best of the potato sections of the district.

In the San Luis Valley, which is an old lake bed, there are considerable areas that are inclined to be gravelly, although the soils there vary from light sand with gravel subsoil to heavy clay or adobe. Some of the best potato soils are those of the river bottoms, composed of river sedimentation and wash from the surrounding hills.

On the West Slope the deep red sand stone soils are among the best adapted to potato growing. The gray wash or till soils from the hills are also good. The Carbondale district and some of the mesas of the Uncompahgre and North Fork Valleys are of the red sand stone character and are particularly adapted to this crop.

Adobe Soils in these districts are often used for potatoes but with constant risk of bad seasons and damage from soil diseases, owing to the tendency of these soils to become puddled. Greater care is necessary in cultivation and in irrigation, and even where the greatest care is used rains frequently compact the soil so as to stop tuber formation. This is particularly true of the soils on the college farm.

Potatoes Unsuccessful on Most Heavy Soils.—We have planted potatoes on this kind of soil at Fort Collins for the past five years. The cultural methods used have been similar to those which give

*Their most common soil is that which is designated by the Government Soil Survey as the Colorado fine sand. Other soils of the same district are those known as the Billings loam, Colorado sand, and Billings clay loam. The soils of the river bottom known as the Laurel sand loam, also grow potatoes.

success in the Greeley district. All these crops but one have been, practically, failures.*

*The first year the cultivation was largely with a shallow cultivator. While the soil was kept loose on the top it was not loosened at a sufficient depth to affect the tubers, and almost total failure resulted.

The second year about two acres were planted on the west college farm and cultivation was given soon after planting. In this cultivation the soil was loosened to a depth below the plowing, or from nine to twelve inches. A second cultivation of the same character was given soon after the plants appeared above the ground. No more cultivating was done but the land was ditched twice with a shovel plow which was equivalent to at least one cultivation. Although this soil is decidedly heavy, these cultivations loosened up the soil below where the tubers were formed. No heavy rains occurred to pack this soil and at digging time the soil was loose as deep as the tubers were set. This year a good crop was secured.

The third year the same ground was again planted to potatoes, making it the second crop after alfalfa, and another plot was planted on freshly broken alfalfa land. The same kind of cultivation was given and the soil kept in the best of condition till the middle of July. At this time the potato tops were sufficiently large to cover the ground and the tubers had reached the size of from one-half to an inch in diameter. Heavy rains following for one week packed the soil to such a condition that a spade was required to dig into the hills. After this packing of the soil there was practically no growth of tubers and although a month elapsed before frost came, and there was no disease of importance to be found, the tubers did not reach marketable size.

The same season a plot of nearly an acre was planted about three weeks earlier than the main crop. Heavy rains followed this planting and caused the soil to become packed and sticky. A good stand of plants was secured but most of the plants became diseased soon after pricking through the ground, and no amount of cultivating could loosen this soil sufficiently to even make a good growth of vines. Almost no tubers were secured from these plots.

The fourth year the same plots were planted again with an additional plot of freshly broken alfalfa land. This year's experience was to a great extent similar to the year previous. Dry weather prevailed during the early part of the season which gave the plants a good start in loose soil; later in the season heavy rains packed the soil about the time that tuber growth commenced. These plants were comparatively free from disease but made very little tuber growth although the vines were of average size.

What tubers were formed in the compact soils during these three years of failures on the college farm, were distorted in form so as not to follow the type of the varieties.

The fifth season (1910) potatoes were planted on another plot of freshly broken alfalfa, with soil similar to the other place. This season heavy rains followed the plowing even before the potatoes were planted. In order to overcome the packing of the soil by the rains a deep cultivation was given this soil before planting. This went far toward putting the soil in better condition but tended toward drying the soil more than was good for the plants. A fair stand of plants was secured, however, and growth was about normal until the latter part of the season when heavy rains again offset the work of deep cultivation. Some marketable tubers were secured but as a whole the crop was a failure.

This experience is not only true of the plots on the college farm, but is the experience of growers for the past twenty years in a large part of the districts along the foothills of the East Slope, and in the Arkansas Valley.

We believe that the character of the soil in regard to being **packed by rains** in addition to their becoming sticky and so excluding air, during

GETTING LAND READY FOR POTATOES.

Preparing Raw Soils.—It is better for the grower to break raw lands during the summer of the year previous to growing the crop. This puts the soil in better condition for taking and holding water and for culture than where the raw soil is broken in the spring before planting. New land in Colorado seldom produces the maximum yield of potatoes, because it is deficient in vegetable matter and therefore in nitrogen, while the physical condition of the soil can never be gotten in the best shape the first year.

The Best Crop for Subduing Raw Lands in Colorado is undoubtedly the potato, even for soils really too heavy for this plant. No crop puts the land in so good condition for the succeeding crop, or for leveling and getting the land into alfalfa. The continuous cultivation of the potato crop, the irrigation, and then the digging in the fall (which is a far better mulch than a fall plowing), leave an exceedingly favorable physical and chemical condition of the soil.

Various Rotations.—In northern Colorado the most common rotation is, potatoes two years, followed by grain as a nurse crop for alfalfa, then alfalfa as a hay crop two years—a five year rotation. Where diseases have interfered with the potato crop, this is sometimes changed to potatoes one year, grain one year, potatoes one year, grain and alfalfa one year, alfalfa two years, then back to potatoes. Where the canning of peas has become an industry, peas have been grown between the two potato years in the place of grains. On the west slope the rotation for the most part is similar to that in northern Colorado. Sugar beets are often used in place of the second year of potatoes.

In the San Luis Valley the rotation is largely potatoes one year, peas one year, grain one year.

Alfalfa, Peas or Clover used in rotation prepares the land for potatoes by improving its physical condition and furnishing the necessary nitrogen. Experiments made by Paddock and Rolfs in the Greeley district showed that the use of a commercial fertilizer

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the middle of the season, is largely accountable for failures to grow crops in these districts. These soils for the most part are not only heavy at the surface but are underlaid by a stratum of almost impervious clay. In the Greeley district even the heavy soils are for the most part underlaid by a gravel stratum which makes good drainage and which appears to prevent the packing of the soil. At almost no time in our experience in growing potatoes at Fort Collins, has there been a season when it was possible to dig into the ridge where the potato plants were growing, with the naked hand. At Greeley it is usually not difficult to dig the potatoes with the naked hand even where they are from six to eight inches beneath the surface. This, we believe, in a great measure accounts for the differences in soils as to their ability to grow potatoes. However, it is found that in the high altitudes and in some places of the West Slope potatoes are grown in soils that are apparently heavier than that of the college farm.

did not materially increase the yield in potatoes and consequently that the expense was not justified. Where manure is obtainable, the yield of all crops for several years is increased very materially. Where potatoes are grown on feeding or dairy farms the manure has very materially increased the yearly total production per acre.

The Breaking of Alfalfa.—Previous to 1886 it was thought that alfalfa could not be broken for potatoes. Up to that time the yield of potatoes in the Greeley district had been gradually decreasing; since that time much progress has been made in the methods of breaking and handling alfalfa land, and the yield of potatoes per acre has shown a great increase. The rotating or small harrow and the two-way plow with five and six horse hitches mark the highest advancement in alfalfa breaking.

Turning Alfalfa Under.—On heavy soil, plowed and planted late, it is not uncommon to allow alfalfa to grow in the spring to a height of ten or even eighteen inches at the last before plowing. This alfalfa is broken by plowing not less than eight inches deep, with a broad or alfalfa shear longer than the furrow width and flattened to sever the alfalfa root before the moldboard lifts the soil.

Heading Alfalfa is a system of great merit growing in use. The land is plowed in the fall or early spring as shallow as it is possible to cut the alfalfa roots below the crown. Then the harrow follows the plow and brings the severed alfalfa crowns to the surface so that they may be dried out and killed. After the alfalfa crowns are dry and dead, a second plowing is given the land, this time going down eight inches or so. Alfalfa *roots* never send up sprouts so that if the root is cut below the crown and the upper portion is killed ,no further trouble will be experienced. The great trouble with planting on alfalfa ground has been that after the alfalfa is turned over, sprouts start from the *crown* and continue to grow during the season. See *Cultivation.*

Clover and Peas used in place of alfalfa give no trouble of this sort but are not equal in fertilizing value, though the soil is left by either in very fine condition.

Irrigating Before Plowing.—While in northern Colorado there is usually sufficient rain to make it possible to plow during May without previous irrigation, still where water is at hand, both at Greeley and in other parts of the state, where the rainfall is less, it is desirable to irrigate before or after planting, and this is best done before plowing. In any case the plow should be immediately followed by the harrow.

The Smoothing Harrow.—The usual practice is to plow from morning until near noon, then unhitch and harrow what has been plowed in the forenoon before leaving the field. The same should be done in the afternoon. This harrowing establishes a soil mulch

and conserves the moisture which is needed to start the plant, and also warms the ground by preventing evaporation. Before planting, the soil should be leveled and thoroughly harrowed, or disked and harrowed so as to secure an even seed bed, fined to a depth of three or four inches.

EARLY POTATOES.

A Hill of Triumphs.

The Early Potato, a Small Plant.—It is impossible for an early potato to rival in production a larger later sort. An early potato of maximum yield is a seedsman's dream. However, we should study to secure from an early sort its maximum yield. This will be done by growing a large number of plants per acre.

A Good Start, above all things else, is the very foundation stone of early potato growing. This does not mean planting before ground and season are ready, but it does mean good soil fall plowed perhaps and everlastingly spring tilled, and ditching, irrigating and re-levelling before planting if the moisture condition be not right. Mellow surface with moisture both shallow and deep are absolutely required for success.

Close Planting both in the row and between the rows with slope enough to run water in small ditches, rich loose soil, special tools for narrow rows,* small footed and narrow tread horses or mules are needed for success with early potatoes.

Low Altitutde is not Essential to the growing of early potatoes. It is best done at from 5,000 to 7,000 feet elevation and such regions can supply the market soon after the Kaw Valley, while from 8,000 feet earlies can supply the market all of September. The cool summers, with slope and sunshine, make it possible to force potatoes with water, in ways impossible eleswhere without causing ruinous disease.

Potatoes in Orchards should be of early sorts so that the irrigation, tillage, and digging may be past in time for the new wood

*Funds permitting, in 1911 and 1912 we hope to work out special tools and methods for growing early potatoes in Colorado.

of the trees to mature well before winter; and early potatoes are one of the best crops that can be grown in an orchard.

Varieties of Early Potatoes.—The Ohio, White and Pink, leads all others of the United States in quantity and quality among truly early sorts. The Irish Cobbler is next and has spread from Maine west and south because it is a handsome white potato, free from the knots and cracks that disfigure the Ohio. It is nowhere (we have inquired and tested widely), good eating, except in our best mountain regions, where all potatoes are good. In Wisconsin, Kentucky, Nebraska, and on our own dry lands, it is inclined to be coarse grained, hard, and yellow fleshed. The Bliss Triumph, of which we have a white as well as a red sort, is the leading first

Potatoes in a Young Orchard

early of the south and is among our best earlies. The Russett and later the Downing, come ahead of maincrop and late sorts.

No First-Class Early potato exists. *The White Ohio,* with its fine appearance and perfect quality, would fill the bill, if it did not run to knots and cracks. *The Cobbler* would be everything desirable if it were good eating, and the same may be said of the White Bliss. We are striving to combine the desirable qualities in one potato. It is a long, difficult and uncertain task in which we are greatly interested.

SEED AND ITS TREATMENT.

Type and Source of Seed are as important as variety. Success also hinges upon such care of the seed as shall keep it in vigorous condition till put into the ground. A big yield of tubers must not

be expected when a poor stand of weak plants is obtained. (See in this bulletin the division on the subject of *Stands.*) For Greeley and the San Luis Valley, where potatoes tend to degenerate after two or three years, the best seed is secured from the dry lands of Colorado, Wisconsin or Minnesota or the unirrigated districts in the mountains. This seed, when planted in the Greeley district, produces the most desirable seed for the succeeding year.

Trueness to the Type of the variety in hand is an essential in selecting any kind of seed potatoes. While their previous history and other things* must be considered in determining the value of any lot of seed potatoes, still, examination for trueness to type, tells us what we can learn from the potatoes themselves, just as in buying a horse, examination of the animal is a part of any proper purchase, although other inquiries are not to be omitted.

Seed for the San Luis Valley.—In some parts of the valley there is trouble in securing good stands because of dry weather. In these places whole potatoes are usually planted. This makes it necessary to plant the small tubers. Where the tubers that go through a one and seven-eights screen at digging time are used for seed, the yield from year to year rapidly decreases, and the best practice is to change seed, securing that from the unirrigated lands of the State at least once in three or four years.

Seed for the West Slope.—In the West slope districts, potatoes may be used for seed year after year with little apparent deterioration in the vitality of the plants. In fact no change of seed has been made on some places at Carbondale since the potato growing industry was started thirty years ago.

The Best Home Grown Seed is secured by selecting the tubers from the field at digging time. This should be done from the best hills rather than by selecting the best individual tubers. The characters that are transmitted by the tuber planted, are more apt to follow the characters of the parent plant than of the individual uber. Therefore, we should look to the vitality, productiveness and trueness to type of the whole plant.

Hill Selection.—*The best method for securing seed is to go through the field at digging time with a fork and dig the plants that appear strongest and most productive. If the plant proves to be true to type and has the required number of tubers, with no scab or misshapen tubers, the better potatoes from the hill are saved for seed. If not, the tubers should be covered up to be dug later with the digger. Some skill and knowledge of the variety is necessary for this work. Where incompetent help is to be depended upon

*See Bulletin 176.

*This has not been successful in the Greeley district. See Bulletin No. 176.

it is best for the grower to take three or four men with him so that the work may be readily directed. This way of securing potatoes is somewhat more expensive, but experiments by Goff of Wisconsin, Waid of Ohio, and results in Germany, as well as in Colorado, show it to be time well spent.

Buy Seed in the Fall.—It is a common practice for growers to defer buying seed till planting time in the spring. When this is done the grower ordinarily knows little if anything as to how these potatoes have been grown or stored. It would be better and cheaper if potatoes were secured at digging time so that the grower can know something of the growing and can make sure that these potatoes have been stored in the best possible manner to retain their vitality.

Storage of Seed.—There is an almost universal belief among growers that, if potatoes are chilled in storage, the vitality is decreased, but no actual evidence is at hand to prove this theory. In fact, our experiments tend to the contrary. In all those districts where snow falls before the ground freezes and lies until late in the spring so as to prevent deep freezing of the ground, so-called *volunteer potatoes* that have lived in the ground over winter, come up in the old fields. Where potatoes are left in the ground over winter without freezing, it will be found that tubers are to all intents and purposes in the same condition as at digging time in the fall. In these cases the tuber, while not frozen, must remain at near freezing point during the whole winter season. The condition of storage that most closely approximates this condition must be best so far as vitality of the tuber is concerned.

Sleeping Period.—Experiments have shown that the tubers must have a resting stage before they will grow. When mature potatoes are dug and immediately planted in the greenhouse, or southern grown potatoes are shipped to the north in the spring and planted, they will not grow till they have passed the resting period. The nearer dormant the tubers can be kept during the winter the better chance they have for making a perfect stand when planted in the spring. The danger from chilling is less than the danger to potatoes from heating.

Heating.—This is the generation of sufficient heat in the pits or cellars to lower the vitality, and often follows freezing. Of course if the tuber is frozen so as to cause decomposition of the tissues, or frozen sufficiently to change the starch to sugar, the vitality will be impaired, even if the buds are not killed.

*Greening of Seed.**—If the seed is kept dormant all winter

*During the spring of 1908, a study was made at the Experiment Station of the effects of leaving seed tubers exposed to the light. Several sacks were spread for a month on the ground in a barn where the

by cool storage, excessive spring sprouting may be prevented by greening. This is done by exposing the tubers to the light. The thinner the potatoes are spread out (certainly not over one foot deep) the better, and the oftener they are shoveled over, the better, which should be once a week, at least, for the last month. Of course it must be understood that the tubers are *not cut* previous to this treatment and are *not exposed* to heat and drying. Greening not only toughens the tissues and produces chlorophyll in the bark or skin, but largely destroys the spores of fungus diseases, and makes the seed pieces less liable to rot. For Colorado conditions, greening is preferable to treatment with corrosive sublimate or formalin, which treatments we do not recommend.

*Treatment for Scab.**—For four seasons, experiments have been made both at the Experiment Station and with growers in the Greeley district, with a treatment of seed for scab. In this treatment the seed was soaked two hours before being cut for planting in a solution of a pound of formalin to fifteen gallons of water. No beneficial results whatever were secured.

Cutting Seed.—In planting potatoes it should be remembered that we are not planting the seed but a *cutting* of the old plant. The question of the size of the cut piece is always before us. The bud with a very small piece of tissue may be taken from the tuber and made to produce a plant. It has been found, however, in various experiments that the yield of tubers increases with the size of the seed piece, up to a certain limit. The reason for this is that the new plant must start its growth from the stored plant food in the piece of potato until it has sufficient root system to take care of itself. If the seed piece is too small or becomes dried there is not sufficient plant food to push it along so as to make a vigorous plant: conversely, if there is more plant food in the piece than is essential for growing the plant the excess is wasted. It has been proven in numberless careful experiments that it pays to use pieces as large as two ounces.†

Two-Ounce Potatoes may be planted without cutting. Four ounce potatoes are best cut in two. In order to have the eyes

strong light could reach them. These tubers were somewhat shriveled from being stored in a cellar where the temperature was higher than was desirable and where the air was too dry. Nearly all became green and many lost so much moisture as to be decidedly dry and toughened. At planting time the potatoes had started to grow but the sprouts were only from a quarter to a half inch in length and were green and tough enough to withstand handling. It was thought that the worst of these tubers were too badly dried out to germinate, so they were planted by themselves, but, to our surprise, nearly all produced healthy plants.

*See **Potato Diseases** in this bulletin.
†See in this bulletin the subject of **Stands.**

evenly distributed, the potato should generally be cut legthwise first. Six ounce potatoes are usually cut first lengthwise, then twice crosswise of the tuber.*

Gauging the Cross Cut.—It is best to make the stem-end pieces larger than the bud-end pieces. With the Pearl, this will nearly always insure at least one eye or bud in each or the stem-end pieces.

Hand Cutting is the only practical way. A few potato cutting machines have been used, but these have never come into general use because machines cannot exercise discretion as to the size of pieces and the eyes contained in each.

Cutting Racks.—The rack most commonly used, and which is the most satisfactory, is like the one shown in Plate VI. This is a slatted, sloping-bottom bin, with a frame for holding a sack open and a knife set at the rear side of the sack holder. The advantage in this is that the potatoes, when scooped into the hopper, are always at the hand of the operator, and instead of holding the knife in the hand, both hands are available for work with the tubers. When one is accustomed to using this device, it is found to be much easier and faster than holding the knife in the hand.

The Cheapest Cutting Device is made by driving a case knife into the end of a piece of board so that the operator may push the tubers across the blade of the knife. Many prefer to push the potatoes in any case, and to drop them thus into the basket or sack.

Do Not Cut too far Ahead.—Potatoes are best not cut more than twenty-four to thirty-six hours previous to planting. If they are left for any considerable time, the loss of moisture is so great as to seriously affect the stand. Similarly, cut seed potatoes in dry, warm, or windy weather must be covered on the wagon with a canvas and must not be left in the field or in the planter to dry out. It is found that the seed works better in the planters when the cut surface is allowed to become slightly dried before putting into the machine.

Dusting Seed.—Many growers think that less disease occurs in the fields where the cut seed is treated with flowers of sulphur or air-slaked lime after cutting. Where this is done, a handful of sulphur or lime is scattered onto each basket of potatoes as fast as added to the sack or on the thin layer on the floor. This dries the cut surfaces so they are at least more readily separated and

*Many growers have thought that the "seed end" eyes were not so productive as or differed from the stem end eyes. We find, however, no difference in their value. At the College, in 1909, two sacks of Pearl potatoes were cut so that the eyes from the seed end, the middle and the base of the tubers could be planted separately. So far as the most careful observation could tell, there was no difference whatever, between the lots, either in time of coming up, the per cent. of stand, the time of maturing, or the yield of these plots.

PLATE VI.—1. A Modern Cutter Box. 2. Irrigating every other row. 3. Plowing alfalfa sod.

work better in the machines. It is claimed by some that this treatment reduces the rotting of the seed.*

PLANTING.

Machine Planters are universally used in Colorado. The chief reason for this is that hand planting would be too laborious and expensive to be profitable, but if hand planting were not too expensive, it would not be satisfactory as machines do much better work than could be accomplished by hand. With the planter, the soil is furrowed, the seed dropped in place, and covered, all within a space of three or four feet, so there is no opportunity for the drying effects of the atmosphere to injure the chance for the germination of the plants. Where the plow and hand dropping is used the soil is very liable to become dried, as the planted tuber is in most cases covered with dry soil.

Picker Planters. — The Aspinwall, Evans, Superior, and Eureka are common types of the picker planter, and while each is different in detail, and some have been more thoroughly tried out than others, they all do practically the same work, are all automatic, and only require one man for operation.

Non Picker Type.—The Robbins Planter feeds the seed by dropping from between the spokes of a horizontal wheel and requires a second man to correct the drop, so that in this case the accuracy of the planter depends on the accuracy of the operator.†

Depth of Planting.—No hard and fast rule can be laid down as to the depth to plant potatoes. Much depends upon the moisture and soil conditions, and slope of the land. Ordinarily, where the soil is in good condition so far as moisture is concerned, and danger of frost is passed, two or two and one-half inches beneath the surface level is sufficient depth, while on flat land, in good condition, potatoes are sometimes planted only one inch deep.‡ Where the soil is apt to dry out, or where planting in dry soil, it is necessary to go deep in order to insure moisture. Deep growing varieties do not need to be planted as deeply as more shallow kinds.

In the Higher Altitudes.—Where there is enough fall to keep water below the tuber bed and where the ground is apt to be touched with frost before the potatoes are dug in the fall, it is well to plant

*Any dust will do the same so far as drying the cut surface of the potato is concerned. Dry Bordeaux mixture was also tried, along with other materials, at the Experimental farm in the year of 1907. This mixture did not prove satisfactory, as the copper sulphate in the mixture tended to shrivel the potatoes and apparently decreased their vitality.

†See the subject of **Stands** in this bulletin, and the per cent. of stands obtained by different machines on the 1910 plots. Robbins planters were used at Greeley and Carbondale; Aspinwalls at Montrose and Parshall.

‡In speaking of depth of planting, it is understood that the depth below the surface is meant, and not depth below the planter ridge.

such shallow growing varieties as Pearl, as deep as four inches below the level.

Width of Rows.‡—With most growers of late potatoes the average distance is 38 inches. This gives room for the planter, cultivator, ditcher, and digger to be used without interfering with the growth of the plants.

The Distance Apart of the plants in the rows depends on the variety and the richness of the soil, and varies considerably in different parts of the State. At Greeley, the average distance in the row we find to be thirteen inches on alfalfa land, and where potatoes follow potatoes or a grain crop, the distance is fifteen inches. On the rich lands of the Western Slope, potatoes are planted as close as twelve inches or even eight inches apart in the row, especially for Rurals on alfalfa land.*

In Dryland Districts, the distances apart for potatoes is much greater, as the plants need more space from which to draw moisture. In this case from eighteen to twenty-four inches is close enough, the closer distance being for early sorts.

CULTIVATING.

Packing of the Soil by the horses' feet when planting is unavoidable on our heavier lands, thus leaving the soil in poor condition for holding moisture, and also for the growth of the tubers. These two things, and the tendency of heavy soils to exclude air, have brought about a system of cultivation, particularly in the Greeley district, that differs materially from potato cultivation in the east.

The Greeley System.—It was found that in order to loosen up the soil and also to kill the alfalfa, it was necessary to cultivate deeply soon after planting. Experience soon taught growers that this deep cultivation, not only killed the alfalfa, but to a large extent prevented the development of diseases by loosening and aerating the soil. Where irrigation is practiced, and particularly with heavy and flat lands, the aerating of the soil is one of the important features in growing this crop.

On Sandy Soils, in some districts of the state, the need for this deep cultivation is not so imperative, although we believe that in all soils in Colorado that are to be irrigated, some degree of this deep cultivation is beneficial, at least once.

Special Cultivators which do this work satisfactorily have been made for Colorado trade. These, while similar to the two horse

‡These distances are all given for the maincrop potatoes. See elsewhere in this bulletin a statement of this matter in relation to **Early Potatoes.**

*See in this bulletin reports of close planting at Del Norte, Carbondale and Greeley, and **Stands** herein.

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Colo. A. E. pl. 36a

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cultivators of the east, are made heavy enough to stand the pull of four big horses and the strain of four shovels penetrating the soil from eight to ten inches.

Cultivation is Begun within a week after planting, or before the sprouts have more than started, the planter having left a ridge which may be followed without difficulty. The cultivator shovels are four inches wide by fourteen inches long, and are moulded and adjusted so as to throw the soil toward the row, and the inside shovels are run so close as almost to throw out the seed.

The Ridge and the Harrow.—After the cultivator is used, the soil is left with a considerable ridge over the row and a depression between the rows. This starts the work of ditching and provides drainage so that heavy rains will not flood the row. The cultivator should be immediately followed with a smoothing harrow, which is run parallel to the rows, for the purpose of making a soil mulch, and breaking down the clods, which are thrown up by the cultivator.

The Alfalfa Roots, or a large part of them, thus loosened and dragged out will be on top of the ground, where they will be dried out and killed.

The Second Cultivation must be delayed ten days or so until the plants are up so that the rows may be followed.

Guards.—In cultivating the second time, it is generally necessary to use guards on the cultivator to prevent the shovels from throwing down and covering the plants.

*Further Cultivation.**—If the work is properly done, these two cultivations will raise a ridge in the land so that ditching is comparatively an easy matter. In many parts of the State these two cultivtions are all that are given, though when the season permits, or when rains are frequent, or in the mountains, between early irrigations and before the vines are too big, it is desirable to cultivate once or twice more. Sometimes the only tool that can be used at last is a small cultivator between the rows. Cultivation of potatoes by the Greeley method is recognized as hard and *skilled labor.*

IRRIGATING.

The Rainfall in northern Colorado for May, June and early July, is usually sufficient to bring up plants and grow them until the tubers begin to form. This is rarely true in the mountains

Irrigation Once Begun must be continued as needed until the crop is developed. Most successful growers hold that in general

*The object of cultivation, rather than any fixed rule, should be kept in mind. If the soil is loose, leave the field alone, do other work against a time when cultivation is needed. One of the best crops we have known of was raised with only one cultivation as there was no rain and the soil staid loose.

too much rather than too little water is used. The number of irrigations required cannot be foretold for any soil or season, and is a matter of experienced judgment based on observing the weather and the actual moisture conditions prevailing under the plant and about the roots, and will vary from two to seven times.* Irrigation must cease before the growth of the tubers ceases, or the potatoes will be coated with dirt, which would have been loosened by the surface motion of growth.

The Per Cent. of Slope affects the methods and amount of water used in irrigating. On the plains, in many places, there is not more than eight or ten feet fall to the mile, while narrow valleys usually have several times this amount. With plenty of slope,

*Some measurements taken on the E. R. Bliss ranch show the amount of water actually used in growing a crop of potatoes, both on alfalfa land and on old potato land. The applications on the potato field, preceded by three years of alfalfa, were as follows: July 25th-26th the water ran 17 hours with a delivery of 4.05 feet per second. August 1 and 2, 27 hours with 1.96 feet per second. August 8 and 9, 24 hours at 2.31 feet per second, and August 15 and 16, 30 hours at 2.37 feet per second. This field contained 17.88 acres, and the depth of water used in irrigation was 13.76 inches. The rainfall by months from April till October was: April, 3.04 inches; May, 1.73; June, 1.10; July, 2.24; August, .64, and September, 2.31, or 11.05 inches. The September rain was mostly in the latter part of the month, and probably did little if any good to the potato crop. If the September rainfall is left out, the precipitation that should be counted as contributing to the growth of the crop will be 8.75 inches. The rainfall plus the irrigation gives us 22.51 inches as the total water used on the crop. The field is Billings clay loam with quite a large per cent. of sharp granitic gravel. The soil is about two and one-half feet deep, underlaid with gravel, so it has good drainage. The field was plowed in early May, eight inches deep, harrowed immediately and planted to Pearl and Snowflake potatoes June 1st. The yield of Pearls on this field was above 150 sacks per acre, which is near the maximum for the season.

The field adjacent to this one had grown potatoes the year before, and was watered just previous to the alfalfa potato field. The first run was 14 hours at a discharge of 4.05 feet per second and the second 18 hours at 1.96 feet per second, the third 16 hours at 2.31 feet per second and the fourth 24 hours at 2.37 feet per second. This field had an area of 19.74 acres, and an average depth of water was used over the field for the season of 9.35 inches. The difference in the irrigating water between the old potato land and the alfalfa land was 4.41 inches. This field was planted just previously to the alfalfa field and the potatoes ripened (or the vines died from fungus troubles) about two weeks earlier. The yield was about 130 sacks per acre, as against something over 150 sacks for the alfalfa land. Frequently a greater difference than this results between alfalfa land for potatoes and land preceded by other crops, but it seems that the difference comes not from the amount of plant food in the soil, but from disease: for, after potatoes have been grown on soil even three years, the cereals grown on it will produce heavy crops.

The difference in the amount of water can be attributed to the mulched condition of the old field and to the physical condition of the soil in the two fields. The decaying alfalfa stems and roots make the newly broken land more porous, and the first irrigation particularly takes more water to fill the soil.

deep ditches are not required; and in fact, where the land is steep, shallow ditches are desirable. Neither is such deep cultivation necessary although thorough cultivation gives the best results in all parts of the State. The length of time required to wet the soil by irrigating varies with the per cent of slope. That is, the greater the fall the greater length of time the water must be run.

Sub-Irrigation.—In the San Luis Valley, where the land is level enough and the subsoil will permit, a system known as sub-irrigation is practiced. For this purpose lateral ditches are run at uniform intervals of from 30 to 150 feet across the field. The water from these ditches in a short time fills the subsoil from the ditches to the center of the spaces, then gradually rises to the surface and moistens the soil. This system has an advantage in ease of operation but is open to the objection that usually more water is used than is good for the plants. The valley has a great deal of soil disease, in consequence, among her potatoes.

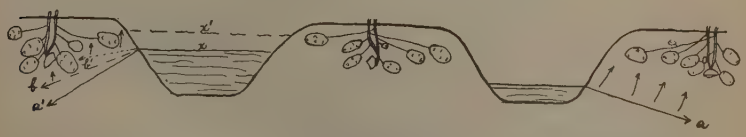

PLATE VIII. *Drawing by C. L. F.*

The Advantage of Sufficient Slope.—Where there is fall enough so the vines or uneven grades do not back up the water in the row at any time, we have the condition shown on the right. The hill space and the dirt about the tubers is not puddled and set, but is moistened like a wick from below as indicated at (a). Ideal slope for all crops including potatoes is about 1 per cent., or 50 feet to the mile.* On much steeper lands, great care is required to prevent heavy washing. However, with good subsoil, record crops of potatoes and grain are grown where the fall is at least 200 feet to the mile.

Flat Lands Not so Good.—Where the fall is slight, very short runs and much labor and skill are required, or conditions will obtain like those shown to the left. With the water level at x, the time must be brief if the soaked portion be confined to the line a′, and it is pretty apt to rise to b and b′, and the hill surface is sure to be puddled to the level x; while with the water level at x′, the whole side hill surface and much of the tuber bed is sure to be damaged.

Accurate Grading of Flat Lands is essential that the existing

*Such slope does not permit of the turning out of large heads at one spot, but requires the substitution of corrugation for flooding, and row irrigation for all fields, to the great benefit of every crop.

general fall may be evenly distributed, and all knolls and hollows are eliminated. A good farm level, a four horse Fresno scraper, with wheelers for long hauls, and infinite labor and perseverance are required for this job, but it pays big dividends in quantity and quality of crop, and in water and labor saved.

FROST.

High Altitude and the close proximity of snow clad mountains make us liable to sudden frosts, both late in the spring and early in the fall. The young potato plants are nipped even in June, early frosts are apt to catch tubers unprotected by a good layer of earth, and our mountain passes render us liable to sudden freezing in shipment.

Growing Potatoes are best protected by water, and air drainage. The bottoms of valleys and such spots as are protected by trees or otherwise from air movement are most liable to frost damage. Recently watered* fields, or fields on which water is running, are least liable to injury by frost. So when a frost is predicted it is wise, other things being equal, to use all the available water, and if the field cannot be all irrigated, to use the water in every third of fourth row.

Protective Ditching and prompt digging are the remedies for frost damage to tubers. The Pearl and other varieties which set shallow, and long or large potatoes or those on long stems which run close to the side of the hill are liable to be nipped by frost. So ditches need to be narrow and straight sided as possible, and the soil taken from the ditch should be spread over the top of the hills. For this purpose there is as yet nothing equal to the Kersey Ditcher† with "side shoves," although we think some of the nearly vertical sweeps may be equipped for this work.

Damage in Shipping is made less liable by putting a false bottom or thick layer of straw on the floor of the refrigerator car and by packing the sides with paper and straw. Salamanders (small stoves) are used to thoroughly warm the cars up to train time, and shippers from northern states are obliged to send men with the cars to tend stoves, but always with a large expense and some losses by fire. In Maine, there is a line of oil heated cars in use to Boston and New York that make shipment safe in any weather. For our use, steam heated cars with thermostats con-

*We might expect the cells of well watered sappy plants to be easiest broken by freezing, but such is not the case with potatoes nor with alfalfa or the leaves of our cottonwoods.

†This ditcher was developed in a district where there is very little fall and is there popular because of its clean large straight sided ditches. It is cheaply made by the local blacksmith and in sizes needed for the slope or variety raised on the particular farm.

trolled by air pressure from the air brake system would be preferable.‡

Danger Dates.—Corn growers and even beet raisers have more time to complete their work in the fall than has the potato farmer, because they are more independent of frost.

The experience of years has established dates past which it is dangerous to leave potatoes in the ground subject to heavy frost losses. Waiting for potatoes to ripen is not wise; it is better to devise ways to ripen them earlier another season and save what is in hand this time.

At 7,000 to 8,000 feet altitude, October 1st is the danger line.

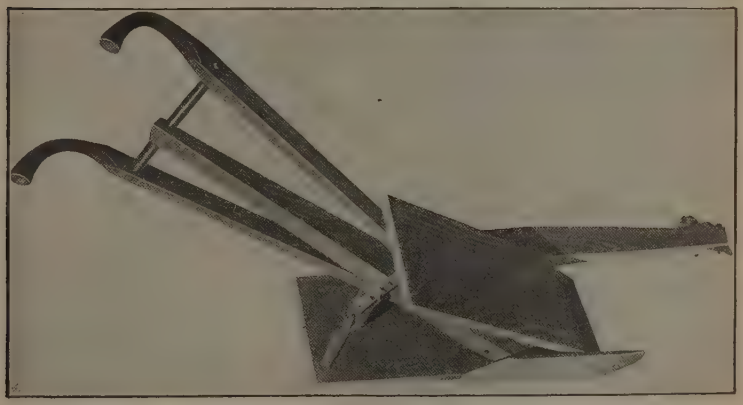

PLATE IX.—The Kersey Ditcher

At Greeley, the leases used to read Oct. 20th, but growers feel safer to be done several days sooner, as damage has occurred on the 16th. Lower still, about Julesburg, for instance, Oct. 20th is quite safe.

Old growers recognize these limits of safety. New ones will do well to adopt them.

CARING FOR FROSTED POTATOES.

When to Sort Them.—The third week after storing is the time

‡The cost of equipping cars in this way is not more than $100 each. Colorado people stopping at at least one hotel in Denver will find this system in use in all rooms, and very quick to respond to a five degree change in the dial. The Burlington Railway is experimenting with a system of this sort, and the Colorado Agricultural Experiment Station, funds permitting, will gladly co-operate with the growers, dealers, and railroads in working out a system to do away with frost losses in shipment. A system of this kind would be particularly useful between the San Luis Valley and Pueblo.

to care for potatoes that have been touched with frost in the ground. The first ten days after the storing, the frozen ones cannot be detected nor sorted out with speed. Frosted potatoes can be told at any time by thumbing the nose of every potato. After the third week they are likely to be semi-liquid rots and to smear the mass past remedy.

PLATE X.—Kersey Ditcher with "side shoves."

Good Light.—Good light is required and cannot be counted upon from open doors or windows at the right time because of the likelihood of storm and cold. Gasoline mantle, acetylene, or electric light is sometimes available. Some cellars in the Greeley district, including the new one at the college, have facilities for skylights in cold weather. Daylight is the best and none too good for the work of sorting out the rots. Frosted potatoes, like balky horses, are bad property. Never buy them. We all have enough of our own.

Sorting from Pits.—This practice always is dangerous, because some years there is no weather that allows the pits to be opened before the long steady cold spells. Most seasons this is a very good way to handle frosted potatoes for storing or selling in November or December. The man who stores frosted potatoes and *does not sort*, deserves scant sympathy.

POTATO DISEASES.

Diseases Differ from Those of the East.—Work done in the East on this subject is of comparatively little value to Colorado potato growers. Every station in the eastern potato growing states has put out from one to a dozen studies on this subject. Nearly

all of these diseases come under the common name of "potato blight," and are caused by various species of fungi that work on the outside of the foliage or stem of the potato above ground.*

Late Blight.—The disease most talked about and which probably causes more trouble to potato growers of the East than any other is that known as late blight, or *Phytophthora infestans.* This fungus came to the United States from northern Europe, its native home†, being the home of the potato in South America. The first we hear of this disease causing trouble to any great extent was at the time of the famine in Ireland during the forties of the last century. The ravages of this disease in destroying the potato crop of Ireland, resulted in the death of 300,000 people in one year from starvation, and brought to a crisis the political agitation and the emigration from Ireland that is only now being abated. This fungus did its first damage in the United States in 1843 and has gradually spread from the eastern states, west, as far as the humidity of the climate would permit its growth.‡

Late Blight Described.—Where this disease is prevalent, it may be seen in early fall, on the lower side of the leaves as a fine mould. When the seasons are comparatively dry with little humidity, the plants seem to withstand the disease, so it will not be noticeable, except that the plants appear to mature earlier than where the disease is prevented by spraying. We found at the Connecticut Experiment Station, that while unsprayed plots showed no particular signs of disease, the foliage appeared to ripen off so that the plants were dead two or three weeks before frost, while sprayed plants were still in good condition until frost struck them.

Damage of Late Blight.—Not only does the fungus kill the vines or injure them so as to reduce the yield, but in seasons when the weather conditions favor the development of the fungus, the tubers decay in the ground, or if infected tubers are taken to the cellar many of them will decay later. This loss by decay is sometimes as great as fifty per cent. of the crop of a whole district. It is not uncommon for this disease to destroy the plants over a large part of a state within three or four days from the time the effect of the fungus is first seen on the plants.

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*For this reason the old, almost universal remedy has been the fungicide **Bordeaux mixture.** It is not uncommon to find Colorado potato growers planning to spray their potatoes for diseases which have never been known in this State.

†**The Potato,** Samuel Fraser.

‡It is not probable that the disease will visit Colorado, for as the fungus lives over winter in the tubers it certainly must have been brought to the State and planted many times in the last ten or fifteen years. Therefore, we may conclude that as the disease has not been found in the State our climate is not favorable to its development.

Early Blight.—Another leaf fungus is that known as early blight, (*Alternaria Solani*), often found in our mountains and less often at Greeley. This disease may be distinguished by black areas with concentric rings on the foliage of the plants in early July or August. It seldom causes rot of the tubers, and is injurious, simply because of its injury to the leaves of the plant. It is impossible to know what per cent. of injury is caused by this fungus as compared with other troubles. In the east, where plants are sprayed with a fungicide, they always give larger yields than where not sprayed, as the result of controlling early blight and the prevention of the ravages of insects and of fungi other than *Alternaria.*

Early Blight Damage in Colorado ordinarily amounts to but little. During the summer of 1909, in early August a storm occurred over Colorado that brought the conditions of humidity that are common to the east; that is, there were some days of almost continuous cloudiness with occasional rain. Early blight developed as a result in nearly every part of the State. In some fields it was so prevalent as to nearly defoliate the plants. If it were possible to know when these conditions were to occur it would be profitable to spray Colorado potato fields.

The Colored Plate illustrates young potato stems affected with the fungus diseases, *Rhizoctonia* (No. I), and *Fusarium* (No. II). Note the plant stems on the left are girdled with *Rhizoctonia.* The stem on the right is affected with *Fusarium* which started by rotting the cut surface of the seed tuber, then followed the vascular system of the plant up the inside of the stems, and killed the smaller sprouts before they got out of the ground.

Rhizoctonia.—Until the last two or three years it was thought that nearly all the fungus troubles of Colorado potatoes were due to *Rhizoctonia.** This disease affects the plant by girdling the stem or root stalk, so as to prevent the food from going from the tops to the roots and tubers, or by cutting off the tuber stems. See the Colored Plate.

Fusarium or Dry Rot.—We have found many fields of potatoes seriously diseased, though the bark of the stem from the old seed to the surface of the ground was clean and free from disease. The leaves, however, were turning yellow, and stopping growth. In some districts this was so serious that many plants died before reaching the surface of the ground. Others grew a few inches above ground and succumbed to the disease. The trouble started principally from the cut surface of the seed piece and followed through the tissues of the old tuber, into the stem of the plant.

*Since publishing Bulletin No. 117, on the Colorado Potato Industry, we have found that a great deal of fungous trouble is not due to this disease.

When the plant stem was split lengthwise, it was found that the sap wood or vascular tissue of the plant was discolored from the base of the stem to some distance above the ground line. The plant was often blackened from the vascular tissue out and in some cases it was rotted off at the base. Investigation was made of this disease and it was found that it was caused by a fungus known as *Fusarium*. In the cross section of the potato stem showing the

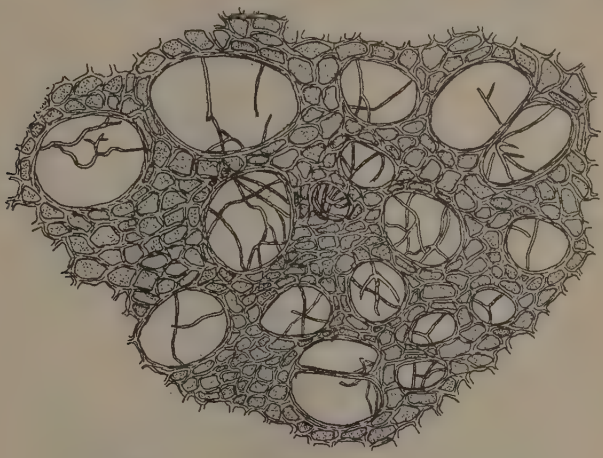


PLATE XII.—Fusarium Hyphae in the Ducts

vascular structure of the stem, the hyphae of this fungus are shown growing across the cell spaces. Apparently this fungus acts on the circulation of the plant, much as roots of cottonwood, willow or alfalfa do in a tile drain.†

†It is probable, also that the fungus does other damage to the plant as well as stopping the circulation. A careful examination of fields in all parts of the State show that this disease is almost always present, more or less. If growers will go through fields in August they will occasionally find plants that appear to be maturing early. They are turning yellow and showing signs of dying. If these stems are pulled up and split, you will nearly always find the yellow discolored area running up the stem just outside the pith tissue. This disease is most noticeable when the plants are young, and in fields where potatoes follow potatoes. In fact it is quite probable that the difference between yields where potatoes follow potatoes, and alfalfa ground in the Greeley district is largely due to the ravages of this fungus. No remedy is known for this disease. Two preventative measures may be adopted: First, that of rotating the crops so that potatoes will not follow potatoes; and the second, cleaning the seed by exposing to the light and air, so that the spores of this fungus will be largely killed, and the tubers made resistant. The planting of a whole seed is always desirable where this disease is liable to occur. The development of the disease is favored by wet soils and high temperatures. Where soils are porous and not too wet, little trouble has been experienced from this disease.

Dry Rot in Potato Tubers is also chiefly caused by the fungus, *Fusarium,* and is most common on bruised or cut tubers and where the potatoes are stored in unventilated or warm cellars, or where dealers and town people keep potatoes in warm places. As stated, the use of such seed is very apt to infect the new plant, to the serious damage of the stand and yield. This matter of dry rot is exceedingly important especially to the growers of Rural and Ohio potatoes and to the consumer. The dealer's warehouse and the out-of-the-way, little-visited farm cellar, set in the field or in some side hill, are great sources of infected seed, poor crops, and unsatisfactory table potatoes.

Internal Brown Spot is a disease affecting, in our region, the tubers of the Early Ohio potato almost exclusively, and though it occurs from California, Idaho and Montana to Texas, we have not known of a case of this trouble under the ditch. It* is thought not to be of bacterial or fungous origin but to be a physiological matter, the death of some of the cells. The cause is supposed to be drouth, and the remedy is the raising of other varieties than the Ohio, and better dry farm methods† that shall supply water enough for the plant.

Internal Brown Spot does not destroy the tuber nor hurt its outside appearance nor preclude‡ its use as seed; but the spots do prevent its sale and as found by the potato specialist in Nebraska and Colorado, seriously damage the odor, flavor and appearance. In close competition, we have found the odor and flavor in samples where the spots could not be seen.

Potato Scab.—This disease occasionally makes its appearance in every Colorado potato field. In the east nearly all writers have thought that scab was caused from a fungus, *Oospora scabies.* German pathologists have proved that several other fungi may cause scab, and in Colorado Professors Rolfs and Paddock found that much potato scab was caused by the *Rhizoctonia* stage of *Corticum vagum.* More recently we have demonstrated that this is true.

*Nebraska is a leading producer of Ohio potatoes and without irrigation, and the disease has been very serious in that State. Dr. E. M. Wilcox of the Nebraska Station and his assistants have spent an immense amount of time on this disease, without isolating any organism as the cause.

†Summer tillage the previous season and summer or fall plowing, with thorough shallow tillage up to and after planting.

‡Sutton & Sons, the well known British seedsmen, performed in 1906 an experiment as to whether tubers affected with this spot were good seed. They found with two varieties that the healthy seed produced a larger crop by one-fourth to one-half but that there was not more brown spot from the affected than from the unaffected seed. In fact there was far less from the affected seed, doubtless because it grew less rank and used less water and suffered less from drought, which in Great Britain, as with us, is thought to be the cause.

I

II

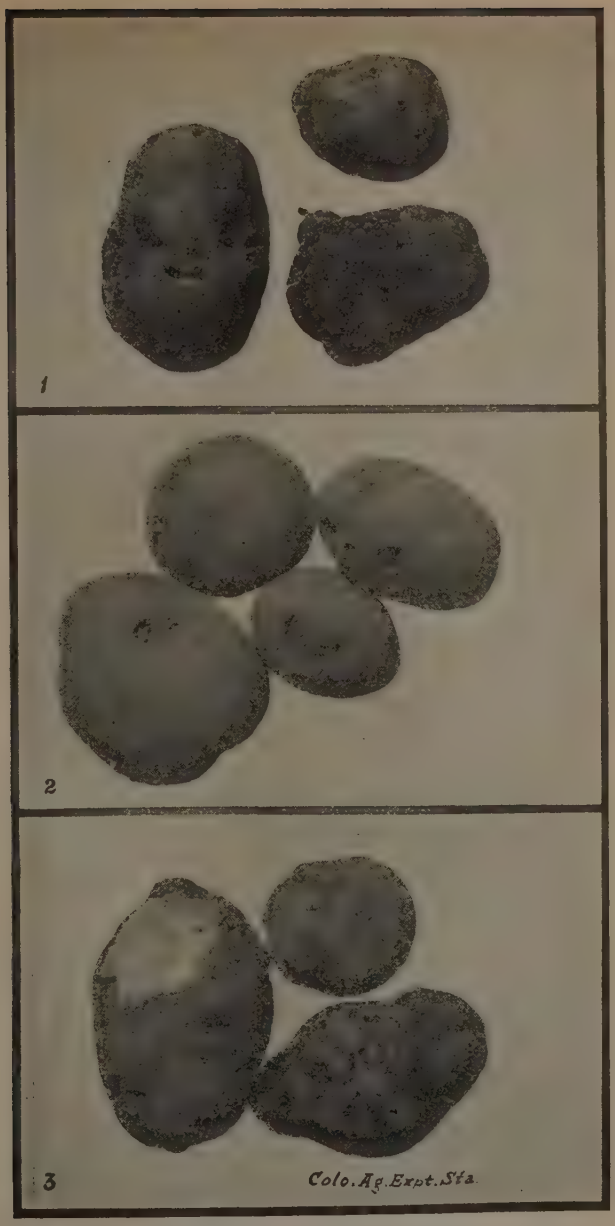


PLATE XIII.—Scab of Potatoes
1. Surface Scab. 2. Deep Scab. 3. Apparent Scab—work of the Beetle.

Tubers treated with formalin solution so as to preclude any chance of planting the fungus with the tubers, have been grown in pots of soil that were sterilized with steam, and the plants watered with boiled water. When the tubers formed in these pots part of them were inoculated with the fungus Rhizoctonia and typical scab was produced, while the checks were perfectly free from scab. As we know that scab may be produced from a fungus, Rhizoctonia, present in all our soils, we cannot hope to eradicate scab by any treatment of the seed. Rotation of crops with good drainage and cultural methods are the only preventive measure that can be recommended. See under *Seed and Its Treatment*, a report of field trials.

POTATO INSECTS

By S. ARTHUR JOHNSON

THE COLORADO POTATO BEETLE. (*Leptinotarsa decemlineata.*)

Native Home and Food.—This insect is a native of a strip of country which lies just east of the Rocky mountain range and includes eastern Colorado. In its native state the beetle lives upon the wild weeds of the potato family. The chief of these is the buffalo bur, but the beetle is quite a general feeder on plants of this group including not only potatoes, but tomatoes, egg plant, tobacco and pepper.

The Insect.—The adult beetle is oval in shape, about three-eights of an inch in length and a trifle narrower than long. The ground color is yellow and the wings are marked by ten black lines running lengthwise. There are also black markings on the thorax. The eggs are bright yellow when fresh and are generally laid on the under surface of the leaves in patches containing from ten to fifty each. The young are dark red or brown grubs with black heads. The color becomes lighter as the grubs mature.

Life History.—The adult beetles live over winter usually in the ground at a depth of from four to six inches. Where the ground is loose they frequently go much deeper. When the ground becomes warmed by the spring sun, the beetles emerge and seek food plants on which they may feed and lay eggs. They are more or less abundant every year and do considerable damage to early potatoes. The late crops in Colorado generally escape because most of the adult beetles die off before the potatoes appear above ground.

The eggs hatch in from four to eight days depending on the temperature. The larvae feed at first on the surface of the leaf where they hatched, but soon migrate to the top of the plant and eat the tender young leaves which are just unfolding. The young

reach full growth about three weeks later. Soon eggs are laid again and the second generation hatches. Ordinarily two broods are all that we may expect.

Remedies.—The best and most practical remedy is spraying with some arsenical poison. In commercial fields the best machine is a power sprayer drawn by horses. In garden patches a hand sprayer does very good work. *Arsenate of lead,* altogether the best poison, is a white paste which must be carefully mixed in a little water before it is poured into the spray machine. It should be strained through a fine screen in order to remove all lumps which might clog the nozzles. Apply the poison at the rate of six or eight pounds to a hundred gallons of water. The proper time to spray is when the young grubs begin to appear at the tops of the stems. Arsenate of lead does not kill as quickly as Paris green, but it sticks to the leaves much longer and the benefits can be seen for weeks even after rains. *Paris green* is the old standby, is cheaper for a single application, and is still the most used. This poison is mixed with water at the rate of a pound to seventy-five or one hundred gallons. There is danger that this substance will burn the foliage of the potato, and to avoid this, it is well to add the milk from two pounds of slaked lime to each hundred gallons of water used. While spraying either of these poisons the contents of the spray machine should be kept well agitated. Sometimes the pest is confined to small areas. In such cases the insects are often controlled by the use of dust sprayers, which either blow the Paris green out in fine clouds, or dust out the same poison when it has been mixed with flour or carefully screened air slaked lime.*

THE POTATO FLEA BEETLE, (*Epitrix cucumeris.*)

The Insect.—When tomatoes are first set out or potatoes first come up there may often be found on them tiny black beetles which jump when alarmed. They are called the flea beetles because of this habit, though they are not closely related to the flea.

Injuries.—The adult insects live over winter and appear during the latter part of May and first of June. They get their living by eating tiny holes in the surface of the leaves of plants of the potato family, and often attack cucumbers and beans. The insects very often congregate in such numbers that the leaves of the plants appear almost black with them. Newly set tomato plants and young potatotes frequently have their leaves so badly eaten that they

*The suddenness of scourges of potato beetles should be remembered. At Greeley, they had not been very serious for many years, but in 1909 $50,000 was spent in fighting them. In 1910, everybody was ready with poisons and sprayers, and almost no beetles appeared. These beetles are liable to be serious in districts where growers have not noticed any harm from them. The first beetle seen should be a warning to be ready the next year.—C. L. F.

shrivel, and the tomatoes may die. Ordinarily the stand of the potato crop is not seriously injured in this way. Their greatest damage to potatoes in Colorado is done by the larvae which live underground. These larvae are tiny white grubs which attain a length of about a quarter of an inch. The first brood is to be found during June or early July. They frequently cut into and destroy the young tuber stems of the potatoes, thus preventing a regular setting of the crop. The second brood of larvae appear during August and September. This brood bores into the flesh and under the skin of the potatoes, causing a pimply or scabby development, which may cause great waste in preparing the tubers for the table and seriously depreciate their market value.

Remedies.—No satisfactory remedy for this pest is known. The leaf injuries to young potatoes and tomatoes may be largely avoided by spraying the leaves thoroughly with Bordeaux mixture to which Paris green is often added. The insects appear to avoid the parts of the plants covered with these disagreeable substances and to seek fresh tissues upon which to feed. It is not certain where the insects hibernate, but they are often found in the fall in large numbers feeding on stray potato plants or pieces of tubers which have been left in the fields. It is well to clear up the fields immediately after the crop is gathered. These insects are seldom, if ever, found on new ground and are much worse where potatoes are planted in succession.

GRASSHOPPERS.

The Insects.—There are many kinds of grasshoppers, but the species that become injurious have life histories which are very much alike. The eggs are laid in the fall in packets in the ground, containing from thirty to a hundred eggs. Their position is about an inch below the surface of the soil. The insects appear to select places which are comparatively dry in which to deposit the eggs, and we have found most of them this year in patches of weeds and grass under fences, and along ditch banks and roadsides. The young hatch rather late in the spring and do not become full grown until mid-summer or later.

Injuries.—Grasshoppers frequently injure potato fields by invading them from the borders, but this is not one of their favorite food plants. The most serious relation of grasshoppers to the potatoes is indirect rather than immediate. Potato growers depend on alfalfa to renew and enrich the soil. The presence of grasshoppers in the fields newly sown to alfalfa is disastrous, for they quickly destroy the little plants and it is impossible to obtain a stand. This prevents a proper rotation of crops.

Remedies.—The best remedy to employ during the fall and spring is the destruction of the eggs. The first step in this work

is to locate the eggs. Inspection should be made everywhere in the surface of the soil for the pods of eggs. When the infested areas have been located, they should be plowed deeply to bury the eggs, or disced or harrowed very thoroughly to break up the pods so that they will be exposed to the ravages of birds and other animals or dried out before they have time to develop. The earlier in the fall that this remedy can be applied the more satisfactory will be the results. It is better not to trust to one treatment, but to work over these places several times at short intervals. When young, or even when full grown, grasshoppers may be caught successfully in a hopper pan. If this is set on wheels a few inches above the surface of the ground and driven over the alfalfa when that is a few inches high, great numbers may be caught. The best time to do this is in the early morning when the hoppers are on the tops of the stems and somewhat numbed with the cold. A third remedy is that of arsenic-bran mash. This substance is made by mixing white arsenic with bran at the rate of one pound of arsenic to twenty of bran. After the substances are thoroughly mixed, add sufficient water to make a sticky, but not too sloppy material. Some add a little anise or syrup. The mixture should be scattered late in the afternoon or early in the morning so that the hoppers will get it before the hot sun has dried it up.

In the Greeley experiments of 1910 the potatoes were sprayed with Bordeaux mixture to test the value of this substance as a repellant to grasshoppers. The results appeared to be favorable as to keeping off grasshoppers, but indecisive as to the prevention of flea beetle injuries to potato tubers. See *Greeley Notes.*

TO SELL OR TO STORE POTATOES?

A SYSTEM

Selling from the Field.—To sell always from the field is as well as *always* to store. The wise grower will sell out of the field when the year's production is greater than the average yearly consumption of three and one-half bushels per capita; and in such a year he will keep selling whenever any one will buy, no matter what the market, because in such a season the price will show no general rise. It is folly to hold for a price for which the grower thinks he can afford to sell.

When to Hold.—The wise grower will hold, particularly following a low price season, whenever the yield of the country is short of the average need, especially if quality be good and consumption likely to be large.

Crop Estimates.—*The Crop Reporter,* published by the U. S. Department of Agriculture, which is our best basis for judgment, is

sent free to all who ask it, and arrives about the 20th of each month with estimates made on the 1st. Sometimes in error on single states, the "Reporter" is said to have been wrong in its general conclusions for the country only once in fifteen years.

Importation.—Potatoes pay a protective tariff of twenty-five cents per bushel. In 1909, 8,000,000 bushels were imported into the U. S., and when domestic prices reach a high level, the crop in Europe must be considered. Otherwise Colorado growers should consider the general crop of the country paying no attention whatever to the crop prospects in our own state, and but little to the crop in our group of states. Until the Panama canal is finished, Colorado growers must look out for an excess on the Pacific coast, as it must compete direct with us now for outlet.

Good Marketing and the Community.—Public welfare is served by *steady* movement of produce to the consumer. Dealers, transportation companies, consumers and producers, *as a body,* are benefited by regular shipment. Good facilities for shipment over our mountains, and accurate crop information, that the price may at all seasons reflect the supply and demand, are therefore matters of public concern.

STORAGE IN ITS RELATION TO MARKETING.

No Fixed Rule can be laid down for the selling of potatoes. Constant study is essential to success. The prices and the best markets vary from year to year, according to the relation of supply and demand in different places. While the demand for potatoes is a constant one in every city, town and hamlet in the United States, the supply varies, and some regions are supplied locally one year and the next year have to ship in potatoes; while the cities and the south are supplied with potatoes that are grown many miles distant during at least a part of every year.

The Northern States produce most of the potatoes and have on hand at digging time ordinarily a sufficient quantity to supply, not only the local demand, but the large markets of the country until the early potatoes from the south take their place in the spring.

Commercial Methods.—If the growers were to place the whole product on the market at digging time it would necessitate the storing of from fifty to seventy-five per cent of the crop each year in the local warehouses in the growing districts. As direct shipment to consuming centers is essential to economy, storage at jobbing points is out of the question, while storage at southern consuming points is too warm or too expensive.

Storing a Large Part of the crop in the districts where the potatoes are grown and shipping as demanded for consumption is better from every economic standpoint; and the temperature in potato growing states favors the plan of storage on the home farm

or local warehouse. In those districts where the winter climate is particularly severe, and where it is difficult because of cold weather or bad roads to take the potatoes from store house to market there is more of a tendency to sell potatoes direct from the field regardless of price at digging time, and in districts where the rainfall is excessive there is also the objection that storage houses are not so easily kept dry as in the arid regions of the West

In Colorado there is seldom a time when potatoes cannot be taken from the farm to the market. As a result our potato growers have taken advantage of the favorable conditions for storing and a characteristic and unique system of storing has been developed. Our growers thus avoid glutting the markets during the digging period in the fall, and take advantage of any brief bulge in the price during the winter. The history of this system shows that it is not an invention but a gradual growth from the idea of storing in pits to the perfected ventilated potato cellars that are found in Colorado today. This system we consider one of the great features of the Colorado industry and is well worth the careful study of all potato producers who do not already understand its principles.

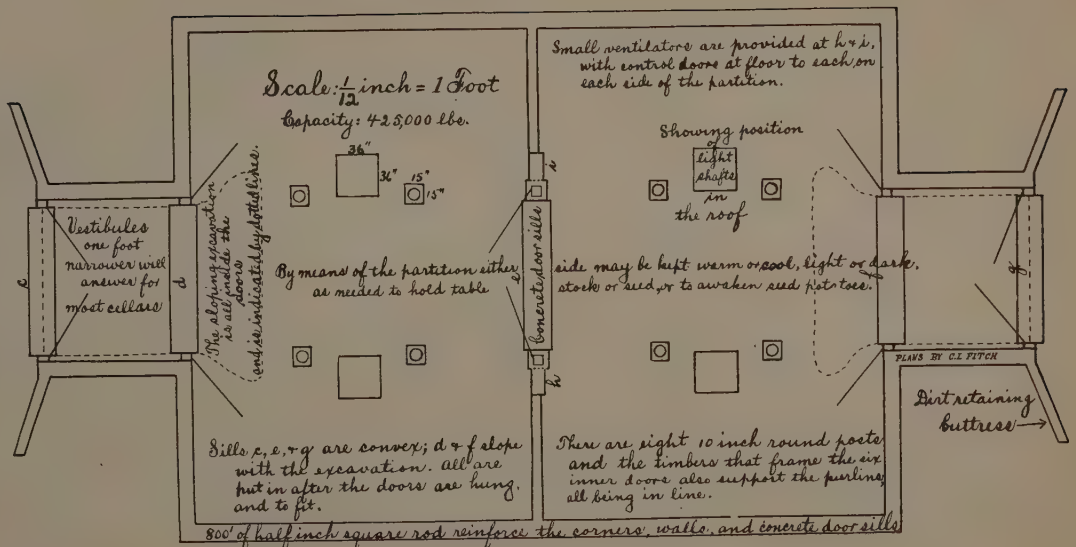
POTATO CELLAR CONSTRUCTION AND MANAGEMENT.

Cost of Construction per Hundred Weight of Potatoes.—This, in the best grade cellars, is about 20 cents. With a permanent roof over the dirt roof, the cost will be at least 5 cents more, and if a grower wishes to provide for seed potato storage, and have a handsome cellar for sales purposes, he may spend as much as 30 cents per hundred weight of potatoes to be stored. On the other hand, with cheap construction, without much regard to permanence, and with the use of farm labor, as little as 7 cents per hundred weight on a large cellar may provide good safe storage. Interest and sinking fund on this basis make the cost of cellar as a minimum one cent per hundred of capacity per year.

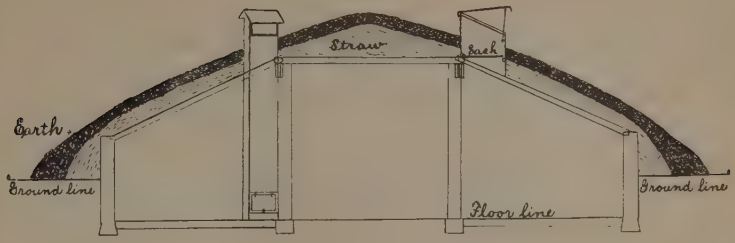
Size of Cellars.—Each square foot of floor space within a cellar will carry 200 pounds of potatoes, piled five feet deep, or 240 pounds per square foot six feet deep. Thus a cellar 50x100 feet will hold one million or one million two hundred thousand pounds of potatoes, with the driveway filled. It is wise to have a cellar large enough to care for the crop if piled four feet deep.

Driveways and End Doors.—A large cellar should have a driveway clear through it, with doors at each end. This saves backing into the cellar, or makes the potatoes at each end accesible, when the cellar is full. It also makes quick and complete ventilation easy. At the same time driveways take space, and the extra bulkhead and double doors are expensive, and let in cold, so that small cellars are often built with only one doorway. Such cellars should be arranged, however, so the center at the rear can be emptied early

PLATE XIV.


Scale: 1/12 inch = 1 Foot
Capacity: 425,000 lbs.
36"
32"
15"
15"
Vestibules one foot narrower will answer for most cellars
The sloping excavation is all paved to the doors and as indicated by dotted lines.
By means of the partition either side may be kept warm or cool, light or dark, as needed to hold table
Concrete door sills
Small ventilators are provided at h & i, with control doors at floor to each on each side of the partition.
Showing position of light shafts in the roof
PLANS BY C.I. FITCH
Dirt retaining buttress
Sills c, e, & g are convex; d & f slope with the excavation. All are put in after the doors are hung, and to fit.
There are eight 10 inch round posts and the timbers that frame the six inner doors also support the purlins, all being in line.
800' of half inch square rod reinforce the corners, walls, and concrete door sills

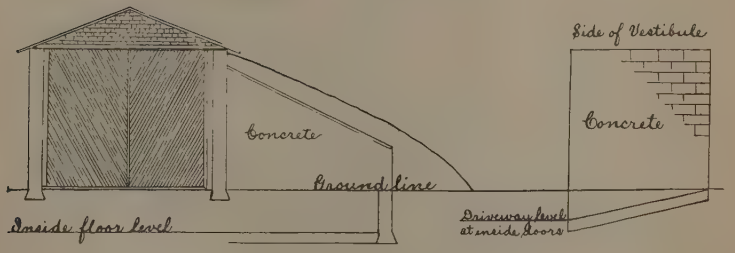
Scale: $\frac{1}{12}$ inch = 1 Foot

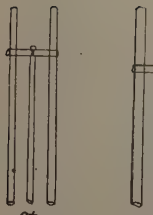


A FARM POTATO CELLAR WITH PARTITION AND ARRANGED FOR LIGHT, DARK, COOL OR WARM STORAGE

PLANS BY C. L. FITCH.

DETAILS OF CONSTRUCTION



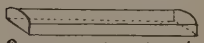


at Ventilators

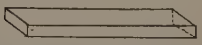
at Light Shafts

Framing Details

Flaring buttress to hold pack of dirt at doors



For outer and central doors



For doors on sloping excavation

Reinforced Concrete Door Sills

in the spring, because it is at this point that most heating and sprouting occurs.

Side Chutes vs. Inside Unloading.—Wide cellars require driveways; narrow ones do not, unless for ventilation. Inside unloading means a vast deal of lugging and stowing away, which in practice involves tramping upon potatoes and rough handling of sacks. By arranging an inclined driveway about over the side walls, chutes may be used, that, with a considerable saving of labor, will permit cellars up to 40 feet wide to be filled quickly from above. Such chutes should be square, about 15 in. x 15 in., set at an incline, and fitted with a slip-over cover of wood, iron bound, but unhinged. If sacked potatoes are to be stored for a time, chutes 22 inches square are required, smooth inside, with a smooth inclined trough below and a table to receive the sacks and of height convenient for the man who piles them up.

Unloading through Chutes.—The wagons should drive within two feet of the chute. A tapering trough, with slatted bottom made of large quarter-round running lengthwise is leaned against the wagon, and is made to fit against the top of the chute. Two men on the wagon handling half sacks of potatoes from the field can keep a continuous stream of potatoes going down into the cellar.

Removing Dirt from Potatoes is important both for appearance and because dirt stops the inter tuber spaces, prevents ventilation and so causes heating, sprouting and rot. Sorters used in the field are the quickest way to sack potatoes, separate the small ones and remove the bulk of the dirt. The slatted trough removes a further per cent., but there will still be some left. When potatoes are dumped inside from sacks, the dirt is well distributed.

Use of a Canvas.—When chutes are used, ten to twenty-five feet of irrigation canvas can be used to let potatoes down without bruising them. The outer end brought up through the chute is turned over and fastened with laths and shingle nails, while a man holds the other end to ease down and distribute the stream of potatoes.

The Leveling of the Top of the potatoes over the whole cellar can be done largely by the canvas. This leveling is best because the projecting parts of uneven piles condense so much moisture upon them, and the top potatoes become so much discolored in the best of cellars, that a perfectly level top is desirable, to have the least possible exposed surface, consistent with proper depth.

Ventilation of the Pile of potatoes is sometimes promoted by using a heavy false bottom of 2x4's with half-inch cracks between the pieces. Others take two 8-inch boards and nail cleats across them close together thus making air shafts for use in the parts of the potato pile deepest or farthest from the side walls.

Dirt Floors Rot Sacks that rest on them if left for more than a week or two, no matter how dry the floor. Therefore floors other than dirt are required for storage in sacks.

Excavations for Cellars should be made deep enough so that sufficient dirt is secured for use about the bulkheads, sides, and roof. Three feet will usually supply this dirt, and this depth makes the slope of the driveway about all that can be covered by the vestibules. Where water comes too close to the surface, cellars must be built upon the surface and dirt found elsewhere to cover them, or sods and adobe brick are used. The cost of excavating the station cellar with the use of day help and teams was 13-8/10 cents per cubic yard, including the piling of the dirt about the hole where it would be handy for covering the roof. A farm level should be used to level the floor of the excavation.

A Knoll is the Best Place for a potato cellar, where available, as the cellar can be placed well into the earth, and still have the slope away from the doors, for surface drainage. Situations should be avoided where water may collect and run into a cellar; and a porous soil without floor is desirable to quickly let away any chance water in the cellar. The worst possible place for a cellar is secured when it is set into a side hill, and especially if set in endwise. If a knoll is not available, the level ground without shelter is the best place.

Side Walls of Cellars are usually required. Some soils stand up firm enough to use for walls without reinforcement, and will carry the plate and rafter ends. Caveins of side walls are disastrous, however, to cellar, crop and life, and it is seldom wise to trust to the earth alone. The cheapest practical construction requires good posts set deeply next the side and carrying the plate on the tops. Planks on the outside of these posts next the dirt are an improvement usually essential, or poles may be laid in. Reinforced concrete is the most permanent side wall, and appeals to those who can afford the best.

*Light is Important,** and ventilators should serve also the purpose of windows. Darkness is demanded for table stock, because greening by light develops the acrid taste characteristic of exposed potato tissue. On the other hand, light combats disease in seed potatoes, toughens the skins, and is a check to excessive sprouting. Cellars should have light in the spring without warmth.

Vestibules should be long enough to leave no sloping driveway outside. Some of the slope can be run within the cellar if required. A good roof and double doors well fitted are needed. A bar will keep out stock when the doors are open, or half doors can be used for this purpose. With good door sills, it is best to fasten the doors

*See elsewhere in this bulletin the discussion of **Greening of Seed.**

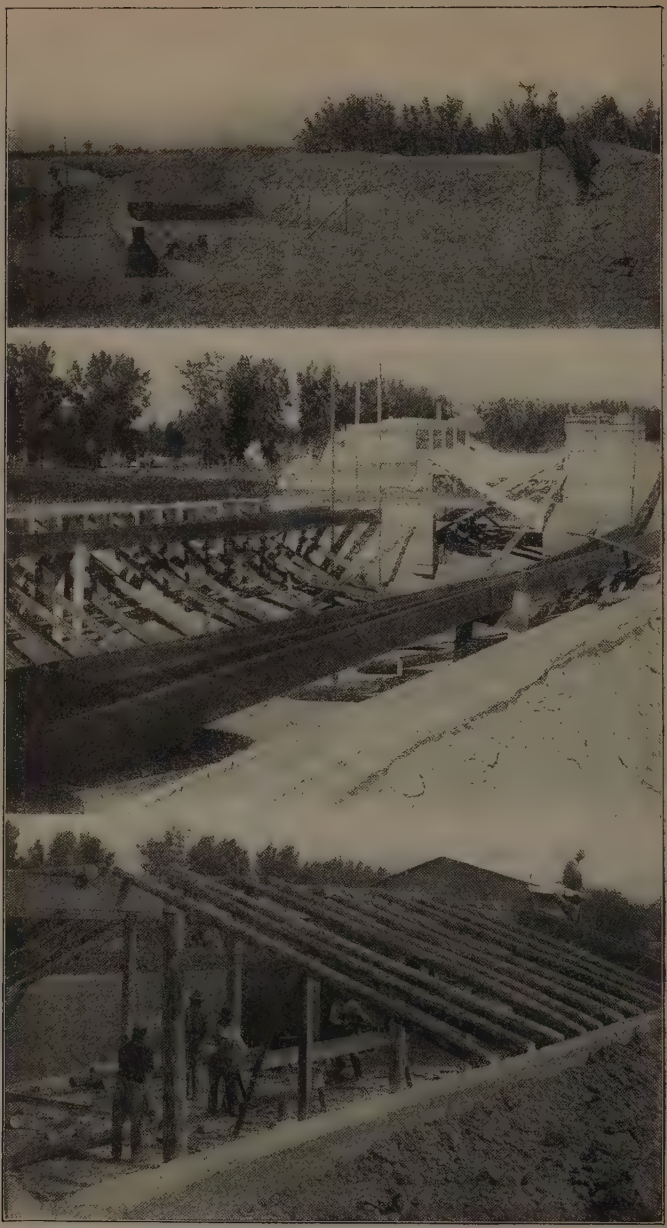


PLATE XVI.—The Station Cellar. Excavation. Braced Concrete Forms. Framing the Roof.

PLATE XVII.—Potato Cellars
1. Strawing. 2. Exterior. 3. Interior.

with top and bottom bolts rather than to a cross bar. Chains or straps and staples and pins should be provided to hold doors safely when they are to be left ajar; and some provision should be made to hold all doors securely open or shut to protect them from damage by wind and wagons.

The Roof is best made of dirt and straw, not alone for cheapness but because of their superiority as insulating material. In a rainy country a tight roof over the dirt might be required, although our dirt-roof cellars when in good shape leak only during prolonged and heavy storms. Even where concrete construction is used for the walls, it seems wise, as yet, to make a temporary roof, and to expect to renew it once in ten or fifteen years.†

Framing the Roof.—Rafters should be sound poles 4 inches at small end, set 15 inch centers, or 2 x 12 sawed stuff. Purlines should be built up of two or three 12-inch planks. Posts should be not more than 10 feet between centers at the most and should be at least 8 inches at upper end. Two rows are sufficient in a 36 foot room, but four lines of posts are required in a wider cellar.

Good Foundation for the posts and walls is required. The roof is extra heavy at times of rain when the foundation soil is liable to be soaked. Gravel or cobble stone bottom is firm but clay subsoils are often semi liquid when soaked, and on such foundation the largest flagstones are required beneath the posts and side walls.

Cost of the Experiment Station Cellar.‡—Gravel, 61 loads, $76.50; poles, $73.15; lumber, cement and paint, $315.30; hardware, $59.85, including square rods for reinforcing; sash, $7.40; contract work for erecting forms, mixing and putting in concrete at $3.25 per cubic yard, $191.00; working foreman at $4 per day and railroad fare from his home, $87.20; straw, $6; labor, $332.85.* Total: $1,149.25. See Plates XIV, XV, XVI, XVIII.

Farm Costs of a Similar Cellar.†—The cash expenditure on a farm for such a cellar will be reduced from the above by omitting charges for horse labor, by the use of efficient farm help, by the substitution of old digger chains for boughten reinforcement, and in

†Reinforced concrete over dirt and straw would make a permanent job, but is in the experimental stage, and is too expensive for trial by individuals.

‡The potato specialist built the cellar rather than let a contract, so he could keep an account of costs. For administrative reasons, the construction was delayed into potato harvest, and he was compelled to hire a competent foreman.

*This includes carpenters and painters at union rates, and team work at $4 per day.

†The best farmers reckon cost of teams as well as of wear and tear on wagon and tools, cost of board and value of their own time, in calculating such a job.

other ways. A clever hard working farmer can put up such a cellar for a cash outlay of about $900; or if he omits the doors, vestibule, and bulkheads at one end, as he may very well do on a cellar of this size, his expenditure need not exceed $750.00. He may erect such a cellar and add a permanent water tight roof for about $900 cash out of pocket.

It Pays Best even with present prices of material to build strongly but cheaply, expecting to build over again when required. This is the business view: but a permanent structure like the station cellar appeals to the man who can afford it as a part of his farm home, for his own and his family's satisfaction.

Ventilation of Cellars is important, but is usually secondary to correct temperature and is ordinarily sufficiently accomplished in connection with air movement secured in proper temperature control.

The Cellar is for Cold Storage, and should be regarded as a place for maintaining proper and even temperatures. In the fall the ground is warmer than the night air, and this night air is our source of cold. In the spring, the ground is colder than the air except in the cool of the night and early morning, and at these hours we must get what ventilation and increase of coldness we can.

Late Evening and Early Morning attention is a requisite. On many fall and winter days doors need to be left open or ajar until, bedtime, and in the spring, doors must be kept tightly shut all day and cannot be opened until bedtime, and should be closed soon after sunrise.

Potato Cellars Close to the House are therefore much better than cellars in the field. The house, where possible, should be at the point nearest the shipping station, which is usually the trading town, in order to save any back haul of the heavy tonnage per acre produced by potatoes. The saving in time of grower and workmen in going back and forth to the cellar in the winter and spring, and the better control of temperature thus possible, more than offset in most cases the economy of team labor at harvest time effected by field cellars.

Correct Temperature for a potato cellar is just above freezing. Good management can hold it within two degrees above or below a standard of 34° F. all the main part of the winter; can get down to this standard quickly in the fall, if the cellar be close to the house; and can fight off the spring rise in temperature for a long time, but late evening and early morning attention are indispensable.

Thermometers Correct at 32° F. by test in slush of snow or chopped ice and water are required for this work, and should be tested before purchasing. The cheapest makes are all right, if so tested and found correct. Three at least are needed—one or more

PLATE XVIII.—Getting the Station Cellar Ready for Straw. End and Side Views of Completed Cellar. Photo by Sackett.

in the cellar, one outside at the cellar, and one on a post near the house.

MARKET STANDARDS: POTATO SHOWS.

A Higher Standard for Size prevails in Colorado than on the Chicago market. There a screen 1½ inches in the clear was standard until recently a 1¾-inch was adopted; here a screen 1⅞ inches in the clear is required, and a 2-inch screen is sometimes used.

Poor Sorting Bad Policy.—While it may pay the individual grower for the time being to sell poor and small potatoes and dirt, it does not pay the individual grower in the long run nor the district at any time. The general rate of consumption depends upon satisfaction and quality, and the market and price for any particular district depends very directly upon good goods and reliability.

Inspection Systems have been devised by dealers* for their protection, and by the Weld County Farmers' Club for the good of the Greeley potato district. While there are delays in getting any of these plans put into use, because the progressive element cannot lead the conservative element too rapidly, inspection is as sure to come as were pure food laws and the prohibition of chemical preservatives in canned goods.

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*The grades for potatoes in force under the Chicago Produce Reporter System are as below:

"Fancy Potatoes" shall be known as: One variety true to name, ripe, sound, smooth, clean, bright, free from disease, scab and second growth, uniform run of medium to large size, correct shape for the variety quoted, with none but would run over a 1¾-inch screen, and not over 5 per cent that would run through a 2-inch screen for round varieties. For long varieties there may be 20 per cent that would run through a 2-inch screen.

"Choice Potatoes" shall be known as: One variety, with not over 10 per cent mixture, but all of one color, ripe, sound, not over 5 per cent scabby, diseased and second growth, fairly clean, good color, medium to fair size and shape for variety quoted, with none but would run over a 1½-inch screen, and not over 10 per cent that would run through a 1¾-inch screen for round varieties. For long varieties there may be 20 per cent that would run through a 1¾-inch screen.

"Good Potatoes" shall be the same as Choice, only there may be a 30 per cent mixture of same color, or 10 per cent mixture of any color and variety, fairly well matured, according to season shipped, and not over 15 per cent scabby, diseased and rough, fair to dark color, fair size, with none but would run over a 1-inch screen, and not over 15 per cent that would run through a 1¼-inch screen, with not over 2 per cent unsound.

"Field Run Potatoes" should be practically sound, but unassorted.

Dockage, when loading potatoes.—In cases where the percentage of dirt, small, inferior, green, etc., potatoes, exceeds the allowance in above grades, inspectors may make said stock equal to the grade quoted, or purchased, by such dockage as they consider equitable.

The section from which the potatoes are quoted, and the general quality of that season's crop in that section, should always be considered in connection with grades; not as really changing above definitions, but in close cases inspectors should favor the shipper if that season's general

One of the Systems for Dealers is operated by a house which also publishes a produce paper and a book of commercial ratings. Where shippers agree to put the system in force at their point, all produce is inspected as loaded by the inspecting company, while its adjusters also operate in the consuming territory, so that unreliability and trickery are largely eliminated. The curbstone shipper and the shortsighted grower who sells to him are the hindrances to the success of this system.

The Weld County Farmers' Club Scheme, in force for the crop of 1909, and considered unnecessary because of the fine quality of their 1910 crop is this: The Club does the work and hires a chief inspector at $100 per month, and sub-inspectors at each loading station, paid by the car. The dealers' association, which receives the first benefits in reliability of goods handled, pays the expense. Certificates are furnished for each car inspected.

Potato Shows should be so arranged that the judge does not know the name or location of the exhibitor.‡ Potatoes should be shown in wire baskets in two tiers. To each basket a tag should be fastened bearing the number of the entry and the name of the variety. On each basket should be laid a card with name of exhibitor and all particulars. Until after the potatoes are judged, this card should be sealed in an envelope bearing the number only on the outside, in addition to the score card, if used, printed thereon.

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crop is not up to the average quality, or favor the receiver if as good or better than usual.

MARKET GRADES: The Weld County Farmers' Club

Fancy Potatoes.—One variety, ripe, sound, smooth, clean, bright, even run of good size, true to type, not over 5 per cent but would run over screen two inches in clear.

Choice Potatoes.—One variety, ripe, sound, not over 5 per cent scabby, wormy or knotty; fairly clean, bright and even in size; not over 10 per cent but would run over screen two inches in clear.

No. 1 Grade.—One variety with not over 5 per cent mixture of same color, or 2 per cent of other color; fairly ripe for date of shipment; not over 15 per cent scabby or wormy; not very knotty or muddy, fair size, run over screen 1⅞ inch in clear.

No. 2 Grade.—Not over 50 per cent scabby, wormy, knotty or green. Not over 5 per cent unsound or that would go through a screen 1⅞ inch in clear.

Disqualifications for show or first three market grades. Screen less than 1⅞ inches in clear. Many knots. Very deep eyes or very irregular shape. For show, any mixture of varieties; for market more than 5 per cent of same color or 2 per cent of different color. Color mottled, splashed, blue or purple. Muddy. Over 15 per cent scabby or wormy or 1 per cent unsound. One-fourth hollow. Sacks not neat, strong, uniform in size. Sacks not securely sewed with standard sack twine.

Trueness to name and type required. No red potato to score as high on color as a white variety; no deep-eyed or long potato to be scored as high on shape as round and smooth.

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‡This is best in any case, and is the only system under which the potato specialist will act as judge.

PLATE XIX.—A POTATO SORTER; and an unsorted sack—one-third smalls and dirt.
ARRANGEMENTS FOR A POTATO SHOW, with cooking tests for sweepstakes.

The Score Card of the Weld County Farmers' Club is as follows:

I. Dealers' Scale.

Size 20	Too large	4
	Too small	10
	Not even	6
Shape 10		10
Skin 40	Not bright	10
	Dirty	10
	Scabby or wormy	20
Quality 30	Unsound	10
	Brittle or spongy or green	20
		100

II. Final Purchaser's Scale

Smoothness	5
Pares thin	10
Flesh white	5
Sound and not hollow	10
Cortical thick	10
Centers small and not watery	10
	50

III. Consumer's Scale

Quickness of cooking	5
Potatoes cook alike	5
Mealiness	10
Whiteness	10
Grain (mashed)	5
Flavor	15
	50

Total Score (perfect 200).

Cooking Tests should always decide the sweepstakes prizes. Growers and the potato specialist alike owe this to their own interests and that of the consumer. Six uniform white enamel pots tagged or numbered, and gas or gasolene stoves to boil six lots at once, together with paring knives, basins, a potato ricer or fruit press, and one or two capable assistants are required for doing this work with dispatch.

EFFICIENCY OF LABOR IN POTATO HARVEST.

Labor Costs More in New Regions.—We have been struck by the low efficiency of labor in the potato harvests of our newer regions as compared with our established potato districts; a difference almost as great as between the labor cost of shoes made by a cobbler and by a factory, and for much the same reasons.

This slowness is a disadvantage, not alone in cost of production, but in increased danger of being caught by a fall freeze.

System and the Best Equipment are Cheapest.—For economy and speed the best sorters must be used; and solid sacks—"Liverpool Returns," the best wire baskets, the best needles, and a high grade of Italian sack twine are none too good. Standard potato wagons are absolutely necessary to the grower who would make most money.

The work should be systematized, and each man have his job. The digger man should feed and clean his horses, and then have his breakfast while others harness the horses, so the digger can run at daylight.

A Day's Work.—In potatoes yielding 12,000 pounds per acre, each picker should put on the sorter not less than 8,000 pounds per day, of nine or ten hours. Where the yield is larger and made up of big potatoes, 12,000 to 15,000 pounds are sometimes picked by a good man; and the grower should be willing to see such a picker in such potatoes make $5.00 a day. It pushes the deal along, and is worth the price, being often cheaper than day labor at $2.00 or $2.50.

In cutting potatoes, 1500 pounds well cut is a good day's work, and 2500 requires a remarkable pace. In planting, four to seven acres should be put in with one planter per day. In sorting up and

PLATE XX.

Three Tons is a Standard Load of Potatoes for a Standard Potato Wagon

sewing good potatoes in the cellar, fifty sacks or 6000 pounds is a fair day's work per man, although expert crews have done three times that amount.

HORSES FOR POTATO FARMING.

Some Farms Can Use Heavy Horses.—The size of the draft animal for a potato farm is set by the work to be done. While 1,600 to 1,800 pound horses are very desirable for breaking alfalfa and for hauling big loads, such animals are a damage in cultivating and digging, and are undesirable on long hauls because they cannot be trotted on the return road and last. Such horses are the thing for the grower close to the railroad switch, who plants wide. Aside from other considerations the smallness of mules' feet and their

narrowness of tread recommend them, especially in the heavier weights, in preference to horses, for potato growers.

An Active 1500-pound Animal the Best.—Horses of not too blocky type, weighing from 1,400 to 1,500 pounds, are the choice of most experienced growers. Five or six such can break alfalfa anywhere; four such can pull a digger all day, if required; and a pair of them can handle three tons of potatoes for the regular load on good roads. This is the standard, net load, at Greeley.

Power Units.—An eighty-acre potato farm should have five horses of this size, and a 160-acre farm, eight. It is cheaper to have them good, and to have only this number; and it is wise to adopt a standard of size, action, color, and harness, and to have only such animals and harness, in order that the units of power may be interchangeable, and make up into two, three, four, five or six-horse teams, of like strength and speed.

The Manufacturer has long considered such items as these in the efficient conduct of his business; farmers have commenced to apply the same principles to their business.

FIELD EXPERIMENTATION

Variety Trials have been continued by the station since 1906 and before. All promising sorts of this country, Great Britain, and of continental Europe have been tried. We feel that we know absolutely the best sorts for Colorado. This work is therefore finished to date, and will be continued only as new sorts arise. It is greatly to the economic benefit of the potato industry to have such work done by the state, and the facts established by clear cut public experimentation rather than by widespread, indefinite and costly private experience.

Seed Changes and Sources are now pretty well understood. The principles involved have been largely fixed, and are formulated in Bulletin 176, and such work as is carried out in the future along this line will be only by way of working out these matters more definitely.

Some New Terms have been adopted in Bulletins 175 and 176. From England we have appropriated the term **ware,** which we think a more useful term than **saleables** or **table stock,** both of which it can well replace. We have used also the English word **maincrop** instead of our indefinite term **late varieties** as opposed to **early varieties.** For instance the Pearl potato is our leading **maincrop** sort, but it is not a late potato. Among variety names we have attempted to establish the better and more appropriate names, always favoring the old as opposed to any new name. The **Peachblow** should not be called McClure; the **Cobbler** is not properly called Eureka; and **Russet** we believe to be most appropriate for the promising new sort which has carried the indefinite names White Beauty and Russet Burbank. Parts of tubers are more definitely named than heretofore, in Bulletin 176.

Future Field Work should be in the development of varieties and strains; in obtaining further knowledge as to the reasons for yield and for running out of seed stocks; in carrying along up to date each year variety trials that we may always have the best; and in the promotion of dry land potato growing for the benefit of the entire potato industry and for the general good of dry land agriculture. Funds permitting, a demand for fertilizer trials at Greeley and Carbondale should be heeded in 1911 and 1912.

One One-Hundredth Part of an Acre is in nearly all cases the basis for the yields given herein. The rows for weighing were in most instances taken alongside each other, and are believed to afford correct and fair bases for judgment of the points in question.

The Potato Specialist, primarily the technical servant of potato growers and consumers, like an engineer to other industries, is used also by the

PLATE XXI.
Assistant Chisholm and Harvesting Kit at Parshall up the Moffat Road.

state as a counselor in person and by correspondence in the development of its newe· districts. While not a teacher, his work is best managed by the Agricultural College. He is a gatherer of information and experience for the benefit of all growers of potatoes, and as such he is a worker in farmers' institutes, where as in bulletins he renders his reports. The far sighted policy in Colorado that has made this work possible, going hand in hand with our natural advantages, must result in a leading position for Colorado among potato states.

STAND

How to Count Stand.—Count 100 hill spaces, as near as can be estimated, including both present and absent hills. Count the skips back and deduct the number from 100. The result is the per cent. of stand. This method is both simpler and as accurate as to measure with a tape the calculated distance for 100 hills and to count the hills present therein as the per cent. of stand.

Causes of Poor Stand.—There are six main causes in Colorado for loss of stand of potatoes: (1) Dryness of seed bed. (2) De-

fective seed or seed asleep. (3) Disease or rot. (4) Defective planting. (5) Large and uneven or poorly cut seed. (6) Cultivation.

1. *Dryness of Seed Bed.*—The upper picture Plate XXII shows a potato field the near part of which had been used for a sheep feed lot the second winter previous and was cleaned up only in time to plow. The pens had been hard tramped and thoroughly dried down deep, while the bents had been well mulched with the litter of the hay, and were in good moisture condition. Potatoes will *sprout* without moisture, but they will not *root* unless moist earth touches the seed piece. Therefore, summer fallowing, fall plowing with spring tillage, or irrigation before plowing, or ditching and irrigation before or after planting, are absolutely necessary to be sure of stand. Potatoes must be planted deep enough for the moisture level to remain in touch with them even if the surface dries after planting.

2. *Defective Seed or Seed Asleep.*—Seed that is slow, from drying, heating, over sprouting or disease may rot before it roots well, so that the little plant loses the impulse of the food in the seed piece. Late varieties may partially recover from such a set back but early sorts cannot. Seed potatoes should be held asleep by cold storing but should be awakened in time to be ready to grow when planted. In moist soil five days from planting we have noted on potatoes that had stubby sprouts when planted, roots three inches long, while similar seed that had not started or had had the sprouts broken off showed roots only 1 to 1½ inches long. *

3. *Disease or Rot.*—Potatoes affected with *Fusarium* will often rot completely before the plants get a good start, or before they start at all. This is particularly true if the seed bed be dry and rains come *after* an interval. And such plants as do start are often killed by the disease soon after or even before they come out of the ground. †

4. *Defective Planters and Planting.*—Not less than 15 per cent. loss in stands the state over is due to this cause, and for the most part to the sort of defective pickers shown in the right of the illustration, Plate XXII, which let go the seed piece in the hopper, instead of holding it, as do those to the left, until the seed piece is

*The greenhouse picture Plate XXII shows one row of Pearls in pots that had been held warm long enough to wake them up ready to grow, and two rows of pots with the same kind which were still dormant when planted on the same date. The plant that establishes itself quickly is much surer to grow and to do well.

† Some experiments indicate that the rotting of seed may be partially controlled by the use of lime on the seed. This is a matter which we hope to take up thoroughly in 1911 and 1912. Rotting of seed already reduces our potato output in Colorado at least $200,000 yearly.

dropped into its place in the ground. We find 95 per cent. of perfect work quite obtainable from our leading planters of either type. The best picker type requires one man who absolutely knows his business. The other type requires a good driver and a faithful, quick and everlastingly patient man or boy behind. We find that one planter crushes the seed about the same as the other, and that one can do as good work as the other. The choice should be made according to the help available. Compare the stands obtained on Pearls at Parshall and Montrose with a picker planter, with those at Carbondale and Greeley, where the other type was used. The annual loss, about a quarter million of dollars, due to defective planters, largely a matter of easy repair, is twice the first cost of the 2,000 planters in use in Colorado.

5. *Large and Uneven Seed.*—Very large seed does not drop as well and is more subject to rot and always results in poor stands. It pays to screen seed to even size in two or three lots, and to cut evenly and carefully, to secure even dropping by the planter. A few large pieces in the hopper are a continued source of lost stand while they remain. It goes without reminder, that seed should not be sliced long but cut as nearly square as possible and always with good eyes in each piece. It pays to use seed weighing as much as two ounces to the piece, and the best stands are always obtainable by using whole seed of this size.

6. *Cultivation.*—The close, deep cultivation required in our heavy and flat lands to combat disease is a frequent cause of large loss in stand, especially in new regions where employers do not realize that potato cultivation demands a high grade of skilled labor and the best tools, as well as accurate planting and straight rows evenly spaced.

ACTUAL LOSSES BY POOR STAND.

Part of Loss Offset.—The following table shows just how much of the loss in hills missing is made up by the hills to each side of the empty place. We find the weight made up much less than some growers have supposed. The first hill on one side of a skip, we call *Firsts.* The next hills we call *Seconds, Thirds,* and *Fourths.*

How Affected by Distance in Row.—When the best distance in the row has been decided upon for the variety and soil, the loss by defective stand appears to be independent of the distance used in the row.

CONCLUSIONS.—From the weight of these 802 hills dug by hand and carefully weighed, as summarized above, we may conclude:

1. Skips in some varieties affect stand to the second hill to

each side, and large skips sometimes affect more than do single skips.

2. Small plants (early varieties) cannot make use of much extra root space; and loss of stand with them gives an almost equal loss of yield.

3. Deep rooting plants like Rurals and Carmens may or may not make use of extra space. There seems to be no uniformity as to the effect of stand on per cent. of culls.

4. If the weights of the thirds and fourths be taken to repre-

Weights of hills dug by hand bordering skips in stand.
Pounds and tenths.

Place	Variety	Sets of hills.	Average Firsts.	Average Seconds	Average Thirds.	Remarks: Screen 1⅞ in.
Del Norte	Sunlight	20	2.3	1.7	1.7	Planted 10x36 inches. Firsts 10% culls, others 16% each.
	Six Weeks	20	1.4	1.3	1.02	
	Noroton	10	1.12	1.14	...	6% and 19% culls.
	E. Ohio	10	1.2	1.1	.92	Uniform % culls.
	Cobblers	10	1.7	1.4	1.2	Firsts & thirds same % culls.
Skips of one hill	Pearls	10	1.4	1.9	1.4	Culls 10%, 5% and 6%.
Skips of 2 or more	Pearls	10	2.2	1.5	1.2	Culls 10%, 10% & 11%. Fourths 1.5. Culls 10%, 6%, 19% and 20%.
	Carmen III	10	1.8	1.6	1.5	
Montrose	Rural No. 2.	30	2.3	1.8	2.0	Fourths 2.1.
Skips of 2 or more	Same	30	2.5	...	...	Planted 12x39 inches.
Kersey	Pearls	20	2.3	2.3	2.1	A yield of 24,000 lbs.
Greeley	Carmen III	18	1.4	1.7	1.1	Fourths 1.3 lbs.
	Carmen III	15	2.0	1.6	1.3	Fourths 1.2. Planted 15x38.
	Blue Victors	20	1.6	1.3	1.3	Fourths 1.1. Yield 14,200.
	Rural No. 2.	15	2.0	1.6	1.3	Fourths 1.2.
	Average of 248 sets of 3 & 4 hills..		1.8	1.6	1.3	Fourths 1.4.

sent the average yield per hill in a perfect stand, then the firsts and seconds recover together an average of .35 pounds, or about ¼ of the loss of one hill.

5. A similar amount is made up on the other side of the skip.

6. *The hills on either side of a single skip make up one half the loss.*

7. *The skips of more than one hill are positive losses of yield except for the weight of one half of one hill.*

STANDS IN GROWERS' FIELDS.

Average Stands 70 to 75 Per Cent.—An extensive examination of stands in fields over the state, in growers hands, convince us that among Pearls and Rurals which constitute nine-tenths of our output, 70 or 75 per cent. is an average stand. An examination of stands secured with these varieties on our plots will convince the reader that a stand of 85 to 90 per cent. is attainable in field prac-

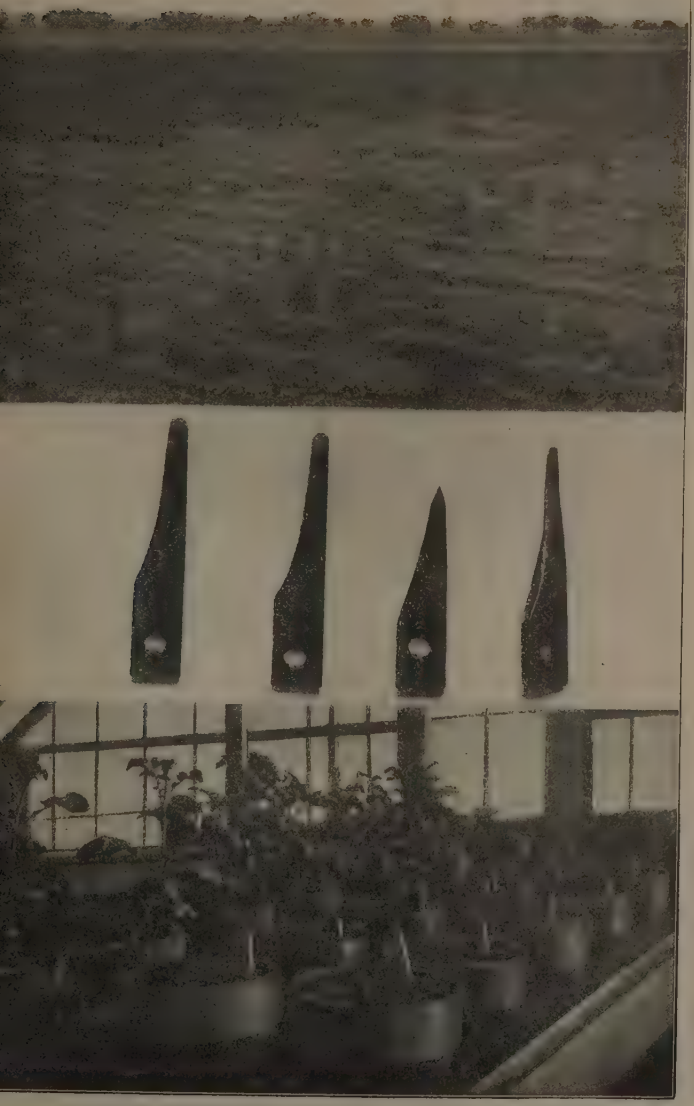

PLATE XXII.—Some Factors Affecting Stands.
Condition of Seed Bed. 2. Picker Points Good or Bad. 3. Seed Awake or Dormant.

tice. Growers have told us they had fine stands, when accurate count showed as low as 70 per cent.

One-Fifth Colorado Crop Lost.—Thus there is a loss of about one-fifth of our crop annually by poor stand, or *half at least of the profits.* The Colorado crop has a minimum value of over $4,000,000. One-fifth this amount is $800,000.

Possibilities of Economic Benefits.—If there can be saved, by educational work and by accurate statement of the facts, one-eighth of this $800,000 for one year, or $100,000, the interest on the saving for a single year, at 5 per cent. annually would support permanent technical work for the potato industry. If one-fifth this loss can be saved annually, it would support the agricultural college in all its branches.

LOSSES BY DEFECTIVE STAND

In per cents of whole crop for stands running from 50% to 95%.

Per cent. stand	Typical skips for each stand stated in left hand column. For every skip ½ hill is made up at sides, the rest is absolute loss.	Stand lost, per cent.	Basis of 100% stand or 100% crop.	Crop lost—per cent on crop secured. 90% standard.	85% standard.
95	5 of one hill each.....	5	3	0	0
90	8 of one hill each and 1 of two hills.....	10	5	0	0
85	9 skips of one hill each and 3 of two each.	15	9	4	0
80	10 ones, 2 twos, 2 threes.....	20	13	9	5
75	13 ones, 3 twos, 2 threes.....	25	16	13	8
70	12 ones, 4 twos, 2 threes, 1 four.....	30	21	20	15
65	12 ones, 4 twos, 2 threes, 1 four, 1 five....	35	25	27	21
60	14 ones, 1 two, 2 threes, 2 fours, 2 fives...	40	30	36	30
55	10 ones, 11 twos, 3 threes, 1 four.....	45	33	42	36
50	14 ones, 5 twos, 1 three, 2 fours, 3 fives...	50	37	51	44

With very early sorts, loss of stand means nearly a proportionate loss in yield, and is much more than is above shown.

Figuring how much he loses by a poor stand, a grower should decide what stand he should secure: 85 or 90 per cent. Then take the line of the table where he finds at the left the stand he actually secures, and in the columns to the right, under his standard stand, he will find his loss in crop, on the basis of what he secures. He will thus be able to figure how much expense he can afford to incur to care for seed and seed bed and to repair old or buy new planters.

DRYLAND POTATO GROWING: Points of Difference from Other Potato Culture

Cheyenne Wells 1910.—The yields here represent the minimum of what need be secured on suitable soils in the plains region. The land was native sod in 1894. It has been farmed each year since, without manure or rotation with peas, nor has it been summer tilled or fall plowed. The natural conditions both of soil and of season could hardly have been worse than in 1910. First class care and tillage with first class seed made a yield that would at least supply food, to a farm home, on the plains.

Rotation with Peas, Beans and Alfalfa.—The results at Julesburg hold out a promise of large yields to the grower who will rotate with

gumes and summer till for potatoes. Pea and oat hay is good hay to oduce milk, and if planted early on rightly managed land is a sure op. Mexican beans are a paying dryland crop. The great interest in od alfalfa seed is sure to result in profitable growing by drylanders of ecial varieties of alfalfa for seed purposes. And rotation with peas or ans and with alfalfa when it has to be plowed up will increase all the rm crops on the plains. See **Julesburg 1910, herein.**

Plowing for potatoes will be done the summer before; or, after sum-er tilling, will be done in the fall. Spring plowing is a gamble. Fall and spring tilling will be universal. Summer tilling will promote good shape in the potatoes grown the next year.

PLATE XXIII.- Planting 2 acres a day with a nter costing 98c Chicago. $1.25 Denver.

Planting is well done deep on the dryland and is one of the things upon which good shape, early set, and good seed depend. It is not advisable to plant with a plow. Use a horse planter or plant as deep as possible with a hand planter.

Cultivate Shallow following cross harrowings. Do not cultivate when it is not needed, but keep out all the weeds and break every crust.

Machine Diggers of the four horse elevating type are often too expensive for dry land neighborhoods while plows are too wasteful of potatoes. The double beam rod shaker digger shown in the cut is a good compromise, as it is cheap and works well on small or mature vines when the ground is loose and not wet.

DEL NORTE

The Good Yields secured at this point commend the soil and care in a year below average for the yields of the valley as a whole. The blights l diseases which in 1910 hurt the earlier sorts, even including Pearls, our Rurals by far the heaviest yielding class. The yield of the Dew-ps (Stake 150) maturing with Pearls we discard because of the un-irable shape of the tubers. The net weight of the Cobblers and the ss weight of the Ohios were about the same, and both were here of table quality, and were ready the first of September. All varieties e dug September 21, and at this date Rurals though thin skinned were aly and white fleshed.

The Productiveness of Sports such as Red Ohios from White, White n Red, Blue Pearls from White, or White from Blue is illustrated at kes 169 and 170.† This has been specially noted with Pearls, and we

*One of the representatives in our present legislature cites his ex-ience that potatoes planted in the furrow that dries out over Sunday e very poor stands. The same is true to some extent of all furrow nting.

†See herein **Mixing in the Hill.**

often hear growers say that they wish they could raise Blue Pearls be cause of the yield. Sports of this sort afford a good starting point fo improved strains, but we do not find the increased yield is long maintaine of itself. We have secured here, at Greeley and at Montrose, from dr land Blue Victors, by means of good conditions and the liberal use c manure and artificial fertilizers to induce variation, about 150 pound of new White Pearls, to be used at Carbondale in starting an improve strain of Pearls.

Close Planting on deep soils here results in great increase of yield and most desirable uniformity of size. Note the yields secured fro stakes 200 to 190. Deep rooting sorts like the Rural respond the best t this practice. Note that the use of double the seed, or 1000 pounds mor per acre, is more than doubly returned in the small seed secured i the crop, and a profit in the ware averaging, on the six lots of Rura 3049 pounds per acre, for the five inch instead of 10 inch planting. Th much more saleable uniform crop is also to be remembered.

Source of Pearl Seed for the San Luis.—Note the difference in th same pedigreed stock of White Ohios, one lot kept the last year at Gre

CHEYENNE WELLS—1910

May 7-9; Planted 24x36.

Stake	Variety and Source	Tota
37	Pearl—Divide	140
38	Pearl—3 yr. Greeley	142
39	Pearl—2 yr. Stove P.	28
40	Pearl—1 yr. Greeley	156
41	Pearl—10 yr. Stove P.	178
42	Pearl—Montrose	122
43	Cobbler—Akron	103
44	Cobbler—Maine	170
45	Cobbler—Mancos	173
46	Carmen I—Maine	191
47	Peachblow—Flagler	248
48	E. Ohio—Maine	228

These were planted by hand, under excellent conditions, and the stand wa practically perfect, except for damage in cultivation.

ley and the other lot at Pagosa Springs. The ware yield of the latter double the former. Note the same with Pearls the sixth year at Greele on the same farm (176) or that the sixth year at Pagosa (175), and con pare again with 173, changed to another farm at Greeley the last yea before coming to Del Norte, and with (200) the yields of big Del Nort grown seed which gave a very poor stand. Compare also the yields fro first, second, and third year Greeley Pearl seed, remembering that of th seed secured in the same neighborhood the "first year" was much th poorer.

San Luis Valley Profits in potato growing **depend on the seed** secure First year Greley seed is much better than that longer at Greeley; see grown at Pagosa or Del Norte from Greeley or (presumably) from dr land or Wisconsin seed is much better still. By the results with Rural a strong presumption is raised that Pearl seed raised by close plantin of the best Pearl seed brought to Del Norte will run enough to seed siz so that the rest of the valley may well look to Del Norte as a source seed, provided only and always that the parentage of the seed offere be known.

Conditions and Parentage: not Place alone are to be considered i the matter of seed changes. To no potato growers of Colorado are th principles underlying these matters more important than to those of th San Luis. See Bulletin 176.

DEL NORTE YIELDS PER ACRE*

In Pounds.

Screened over 2-in. screen and corrected by 3 per cent. estimated difference to 1 7-8 basis.

Stake	Variety and Source	Total	Ware	Culls	Stand
147	Sunlight—Maine	11460	10270	1190	84
157	Six Weeks—Maine	10975	9107	1868	88
151	Bovee—Maine	12240	11136	1104	63
192	Noroton—Maine	5790	4971	819	59
150	Dewdrop—Maine	20740	19661	1079	81
148	Burpee—Maine	12260	11186	1074	73
152	Ohio—Minn.	11088	8562	2526	88
153	Ohio—Divide I	10220	8734	1486	81
158	Cobbler—Maine	12080	10266	1814	75
159	Cobbler—Minn.	12414	10427	1987	83
205	Ohio—Divide II	9540	8385	1155	76
154	W. Ohio—Pagosa	13271	10217	3055	85
155	W. Ohio—Greeley	10350	5174	5176	82
191	White Victor—Del N.	14594	13736	858	..
169	White Eye Pearl—	22806	22404	402	..
170	Purple Eye Pearl—	20700	19251	1449	..
160	R. Seedling—S. Prairie	8100	7323	777	80
161	R. Seedling—Greeley	9540	8386	1154	81
162	R. Seedling—Carbondale	8600	6658	1942	83
163	R. Seedling—Divide	7400	5622	1778	78
168	Russet—Carbondale	7740	6112	1628	..
164	Snowflake—Greeley	9480	6604	2876	89
167	Challenge—Greeley	8040	3301	4739	87
180	People's—Greeley	9440	7953	1487	91
166	W. Prolific—Pagosa	6640	5159	1481	77
172	G. Mtn.—Greeley	8400	5692	2708	88
202	P. of Canon Valley	9600	7168	2432	81
171	Wells'—Wheatland	4680	3434	1246	83
165	Peerless—Greeley	14240	11267	2973	88
176	Pearl—6 yr. Greeley	8240	5927	2313	86
175	Pearl—same, Pagosa	13600	12728	872	78
181	Pearl—1 yr. G. sod	11440	8703	2637	88
179	Pearl—2 yr. Greeley	10080	7742	2338	87
174	Pearl—3 yr. Greeley	9760	7642	2118	89
177	Pearl—1 yr. Greeley	9960	8258	1712	84
173	Pearl—6 yr. Ped.	9280	7398	1882	79
178	Pearl—1st. yr. Ft. Collins	11360	9340	2020	91
182	Pearl—Wisconsin	12320	11249	1071	81
	Same	12800	12384	416	..
200	Pearl—2 yr. Del N.	18000	16210	1790	65
	Same, poorer soil	12550	11776	770	..
	Same, next row 2x10	14700	12241	2459	..
189	Carmen III—Wis.	12840	11295	1545	74
	Same, 2x10	17760	13512	4248	..
188	Rural—1st. yr. Ft. Collins	13080	11192	1888	75
	Same, 2x10	15480	12464	3016	..
187	Rural—1st. yr. Greeley	12240	9967	2273	81
	Same, 2x10	19680	14990	4690	..
185	Rural—Greeley, sod	19920	15178	4742	..
	Same, 2x10	17980	16039	1941	..
183	Rural—Wisconsin	16502	.....	.....	75
	Same, 2x10	17710	15931	1779	..
184	Rural—1st. yr. G., alfalfa	17958	14437	3521	71
	Same, 2x10	22965	19721	3244	..
186	Rural—Greeley, station	15625	13593	2032	82
	Same, 2x10	19800	18234	1566	..
190	Peachblow—Greeley	15000	12810	2190	75
	Same, 2x10	21000	16520	4480	..
156	E. Ohio—Parshall	10800	9564	1236	82
206	Triumphs—1st. yr. Del N.	15240	14017	1223	75

* The planter used here caused a loss of stand of about 10 per cent.

MONTROSE: BOSTWICK PARK

Planted: Earlies 12x39. Late Varieties 10x39.

Stake	Variety and Source	Total	Ware	Culls	Stand
	Earlies on sage brush land in orchard.				
'64	Dewdrop—Maine	4550	4300	250	95
56	Noroton—Maine	1600	1300	300	60
66	E. Ohio—Red River	3300	2600	700	95
57	Triumph—Carbondale	4800	4300	500	76
58	Same—Salzer's E.	....	....	....	76
59	W. Bliss—Maine	4000	3600	400	72
65	Perfection—Maine	5300	4700	600	63
67	Bovee—Maine	4300	3700	600	67
63	Burpee—Maine	5000	4500	500	45
62	Cobbler—Mancos	5700	5200	500	90
61	Cobbler—Red River	5500	4100	1400	77
	On four year old alfalfa sod.				
84	B. Victor—Nebraska	15800	15500	300	95
87	Cobbler—2x10	7000	5500	1500	..
70-a	Duplicate	7550	6050	1500	..
69	Snowflake—B. P.	15000	14000	1000	100
68	Snowflake—Greeley	16300	14300	2000	96
77	"La Follette"—Wis.	13250	12750	500	93
70	Pearl—Pedigreed	12200	11700	500	94
73	Pearl—Stove P.	15300	13700	1600	77
71	Pearl—B. P.	13100	12500	600	91
72	Pearl—Carbondale	9600	9300	300	87
76	Pearl—1 yr. G.	10600	9700	900	94
75	Pearl—1 yr. G. sod	13300	12300	1000	94
74	Pearl—Del Norte	16000	15700	300	94
81	Rural—B. P.	13700	13100	600	96
83	Rural—Eaton	16400	15800	600	95
80	Rural—Greeley	14700	13700	1000	98
82	Rural—W. Sprout	17000	15000	2000	93
79	Carmen III—Wisconsn	18600	17400	1200	92
78	Downing—Montrose	12500	11600	900	95
85	Peachblow—Greeley	12000	9500	2500	93
86	Peachblow—Carbondale	14100	11100	3000	88
87	Russet—Carbondale	12900	10400	2500	93

Earlies here had a poor start due to deeply dry soil and, as at Greeley, to drouth. And early potatoes cannot make up for lost time, as is noted under the division of this bulletin **Early Potatoes.** The excellence of the Triumph and the Cobbler are corroborated, and on the alfalfa sod increased yields were obtained from close planting of Cobblers.

Maincrop Potatoes suffered severely not from a poor start, for they had a good one, but from the breaking of the ditch and dryness in midseason. The large yields of both lots of Snowflakes as compared with others is a feature, while the Downings and Russets again give good yields as secondary sorts.

Among the Pearls, note the capacity of the Stove Prairie dryland seed to give a good account of itself in hard conditions, as was shown with dryland seed Pearls at Greeley. This same idea applies to the Bostwick Park sage brush land Pearls,† the Greeley sod Pearls, and possibly to the Del Norte pea land Pearls as compared with those grown on alfalfa land at Greeley and Carbondale, and it is a general principle, that good seed does better when taken to richer conditions than those under which it grew.

†See results with Bostwick Park sage brush land seed at Julesburg and Greeley, and of Parshall sage brush land seed at Greeley. Sandy land with enough slope and the early irrigation possible at high altitudes, we believe to be factors in the success of this sage brush land seed.

Among Rurals, note that all imported stocks exceed the home seed, and that a Rural seedling, Carmen III, Wisconsin grown, leads them all, while seed, pear-shaped, grown at Eaton near Greeley comes second. This seems to argue for change of seed stocks in this locality.

White Sprouted seed is found among all the Rurals of the Montrose istrict that we have seen, and their white blossoms are conspicuous among he purple in the fields. This is a serious defect to the eyes of a potato lan in the otherwise wonderful Rurals shipped from the Uncompahgre, nd we thought to find that a selection of the white sprouted sort at lanting time would show a lower yield. Such is not the case. They xceeded the Rurals from the same lot by 3300 pounds gross per acre nd by 1900 pounds net. Their shape is, however, inferior and is still orse in poorer conditions.* The white sort is doubtless Carmen I. See s yield at Greeley.

CARBONDALE

Record Yields for unmanured, unfertilized field culture were here btained on our plot. Such was the uniformity of yield at the upper and ower ends of rows and from one side of the field to the other, that we elieve that the whole piece would have gone the same as any part if lanted to the same sort.

Early Sorts.—Note the 2800 pound increase in the Cobbler yield by he 5½ inch planting (A and B) and that at stake 128 the very earliest orts were made to yield 20,000 pounds per acre by planting in 20 inch ows and cultivating with a beet cultivator.† The excellence of the usset as an early potato is here as elsewhere strongly indicated. (Stakes 29 and 130). Note also that it responds here strongly to seed selection. he more oval seed produced 6257 pounds more ware per acre than the im seed.

The Snowflake has been a famous potato. Believing that the great ork done by Carbondale growers with the Peachblow and the Triumph ould be repeated with the Snowflake, we sorted over a large quantity of reeley Snowflakes, and planted the best, to be hill selected here, and then rown on the dryland, to be thence supplied in 1913 to all the State, as a ome favorite potato. The yield (S. 126) promises success.

The Pearls, especially the locally developed Pearl, called Valley Prize, ave remarkably high net yields, without knots, cracks, hollowness or her defects. Stake 134 had a net yield over 1⅞-inch screen of 598 ushels, and the next highest net yields were of Pearls from Pearl seed rown in the valley at Carbondale, and at Greeley, and from Messrs. weets' Peachblows and Gold Coins.

That Rurals were Omitted from the Carbondale lists is one of the versights of a strenuous season. This variety now leads all others in he United States. From what it does at Del Norte and Montrose and private hands at Carbondale, we do not hesitate to recommend it for anting beside the Peachblow as a **late sort.** It will doubtless lead all her white potatoes in yield, uniformity, beauty,‡ and high quality at arbondale. For **medium,** the Pearl will be standard. For **early** the usset and the Cobbler promise to be standard. We would not at Carbonale go outside this list. It has been a misfortune that all varieties do ell here.

Close Planting will be the thing for Rurals, as close as four inches erhaps. At 124, note that the Peoples gave a good profit on using vice as much seed, and that when three times as much seed was used it turned in the crop. This 3-2/3 inch planting also gave a much inreased percentage of seed size. Compare also Pearls so planted at stakes 38 and 139, where the closest planting reduced the yield but produced ore seed. See also Del Norte for close planting of Rurals and Peachows.

*The new sage brush lands of the Uncompahgre should develop a ade for seed Rurals but will find that pure seed will be demanded.

†See **Early Potatoes,** a division of this bulletin.

‡Rurals come out of the ground clean because of their smooth skin.

CARBONDALE—1910

Planted 11x38. 1 3-4 Screen used and corrected to 1 7-8 basis by addition of 2% to culls.

Stake	Variety and Source	Total	Ware	Culls	Stand
A	Cobbler—11 in.	18100	15928	2172	93
B	Cobbler—5½ in.	20900	.....	....	93
C	Sunlight—Maine	28600	.....	....	97
D	Dewdrop—Maine	31600	.....	....	100
E	Perfection—Maine	17789	.....	....	90
128	Earlies—11x20, Noroton	22040	17632	4408	..
	Triumph	18810	15048	3762	..
121	Late Ohio—S. P.	20700	.....	....	85
122	R. Seedling—Carbondale	26642	.....	....	91
123	R. Seedling—S. P.	24200	.....	....	91
124	People—Carbondale	27785	.....	....	96
	Same, 2x11	32393	.....	....	..
	Same, 3x11	33529	.....	....	..
126	Snowflake—Greeley	24600	19434	5166	97
127	F. Snowflake—Maine	34200	.....	....	96
129	Russet—Carbondale	28484	25353	3133*	89
130	Same, slim seed	21700	19096	2604	91
131	Up-to-Date—Carbondale	29464	.....	....	93
132	Peerless—1 yr. G.	29400	.....	....	86
134	Pearl—Valley P.	38000	35340	2660	..
133	G. Coin—Carbondale	30900	28737	2163	100
136	Pearl—Carbondale	32500	28925	3575	95
135	Pearl—Wisconsin	30100	26789	3311	91
137	Pearl—1 yr. G. sod	33200	28884	4316	98
138	Pearl—Del Norte	29900	26312	3588	97
139	Pearl—mixed, planted 2x11	32592	.....	....	..
	Same, planted 3x11	30400	.....	....	..
140	Peachblow—Ault	36300	.....	....	97
141	Peachblow—Carbondale	35700	.....	....	98
	Duplicate	37500	.....	....	..
142	Peachblow—Flagler	37800	.....	....	90
143	Peachblow—Greeley	30600	.....	....	89
144	W. Peachblow—G.	28000	.....	....	94

* Estimated at 11%, following test of 12% on slimmer stock.

PEACHBLOW CULLS AND CRAX

The per cents of smalls, crax and extreme slims were taken on the three highest yielding Peachblows. ("Crax" is the trade-name for cracked potatoes).

Stake	% Smalls	% Crax & Slims	% Ware	Yield Ware
140	8	23*	69	25047
141	7	16	77	28875
142	8	26†	66	24948

* A large per cent. here of slims.
† Almost all crax.

PARSHALL 1910

Our Plot in Middle Park on the Moffat road was a sandy brown mesa loam several feet deep, with lighter colored and heavier subsoil on cobblestone drainage, an excellent potato soil. This was the third crop from sage brush, the previous ones having been grain and turnips. Conditions were very fine when planted on May 6 and 7. The plot did not receive water early enough, and was late when the freeze came on August 25, which destroyed $1,000,000 worth of potatoes elsewhere, and was

the record early freeze at the Experiment Station. Potatoes must have rotation with clover, alfalfa, or peas; and Middle Park is no exception; and such rotation regularly practiced will bring amazing results with all crops grown. This region, especially with a James Peak tunnel, will be the closest mountain potato section to the Denver markets. Early potatoes can be ready at 8,000 feet by September 1. In 1909, our yields of Pearls —a medium late sort—were about 12,000 pounds per acre, on sage brush land at this point.

The Seed Grown on Sage Brush Land, at high altitudes, if watered early, we find good seed for the Greeley district. See Montrose, Greeley, and Julesburg.

The Pearl—first year Greeley or dry land seed—is the best main-crop potato for the Park. Rurals might be better on the heavier soils but are pretty late in maturing. For earlies the Cobbler and the Ohio are the ones to plant.

YIELDS AT PARSHALL

Planted 15x38.

Stake	Variety and Source	Total	Stand
108	Pearl—6 yr. Greeley	3168	95
106	Pearl—2 yr. Del Norte	5040	88
116	Pearl—1 yr. Parshall	5760	93
104	Pearl—1 yr. Greeley	5904	88
120	Pearl—1 yr. G. Sod	5616	95
105	Pearl—2 yr. Greeley	5184	94
107	Pearl—3 yr. Greeley	6048	95
119	Peachblow—Flagler	6348	89
110	Downing—Carbondale	3816	72
102	Challenge—Greeley	5184	88
101	Snowflake—Greeley	3024	70
115	F. Snowflake—Maine	6984	86
109	R. Seedling—Stove P.	3096	48
113	E. Ohio—Red River	2664	94
112	Six Weeks—Maine	2736	95
111	Cobbler—Maine	2160	75
103	W. Ohio—2 yr. G.	1584	95
114	N. Beauty—Maine	1018	70
117	E. Rose—Parshall	3876	74

JULESBURG 1910

Our plot here was an old alfalfa field, a gray loam, deep, with heavy but porous subsoil. It was irrigated early, plowed 8 inches deep, harrowed, leveled, rained upon and harrowed before planting on May 4. There are few soils better than this type at Julesburg. The reservoir of the Julesburg Irrigation District broke its dam early in the season, and the potatoes were never irrigated, while the rainfall was below normal. The potatoes were harrowed before and after they came up, and this was of great benefit. Potatoes intended to be harrowed should be planted deep, so as not to be harrowed out.

Boxing is a British title applied to potatoes sprouted in crates and set out by hand. Quicker growth and better yields are claimed for the practice. The early season was dry and unfavorable for this test. Our conclusions here, at Greeley, and Montrose are that better results are obtained by the use of stubby, sprouted, just started, or greened seed potatoes, in planters.

Wisconsin Seed tested here proved to be 78% Pearls and 22% mixed Rurals and other sorts. Such mixtures are not tolerated in established Colorado potato regions.

Dryland Possibilities.—The most significant result of the work in 1910 at Julesburg and one of the most important facts in Colorado agriculture, was brought out because the reservoir broke, and the plot became a dry land experiment. The yields of 10,000 pounds per acre on the

standard sorts is proof of what can be done on loamy lands with good subsoil, without irrigation, if properly rotated with alfalfa, beans and peas.

Dryland Rotations.—If peas are used they should be planted in the earliest spring time in rows for cultivation and on packed fall plowing or summer tilled stubble. Two years of peas are recommended, the first season cutting for hay, and the second plowing under the crop and summer tilling for potatoes to follow in the third and fourth years, returning to grain for the fifth year and then repeating. By this means all dry land crops will be vastly increased, and the irrigated potato regions greatly benefited by an adequate seed supply. The irrigation given the Julesburg soil before plowing we do not consider superior to summer tilling.

Varieties and Seed Sources.—We have much evidence here as elsewhere that those regions which buy Greely seed should buy if possible first year seed, and this is of added importance if the stock is again to be used for seed. The excellence of the sage brush mountain seed from Parshall and Montrose and the Cobblers from Mancos is affirmed in the yield of Rural, Pearl and Cobblers, and the desirability of dry landers' planting both early and late sorts is again illustrated. The Cobblers did fine and were beauties. We can only wish them equal in table quality to the Ohio. We do not favor for Julesburg any varieties but Rural, Pearl, Cobbler, and Ohio. We believe that this region with good knowledge of type and varieties and the facts of Bulletin 176 can maintain its seed stocks somewhat longer on its deep lands than can the Greeley district.

COOPERATIVE DRY LAND TESTS AT JULESBURG

Four Tableland Farm families* cooperated with us in tests of varieties for dryland growing, and gave most hearty and much appreciated

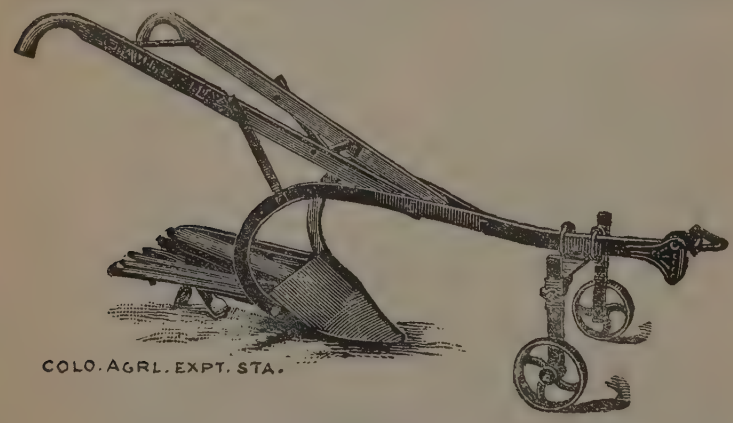

PLATE XXIII.

The Doublebeam Shaker Digger Handles Early Potatoes and Ripe Vines Very Well, and is Much Better than a Plow. Cost, $10.50 Chicago; $12.50, Denver.

aid in this work. On land carefully cultivated but not summer tilled or falled plowed in any case nor that had grown peas, beans or alfalfa, it was proven in this bad season, that dry landers can grow as a minimum 50 or 60 bushels or even more of potatoes. This year Pearls did by far

*We say "families," rather than "farmers," because the women and young folks in the tableland farm homes take their full share of work and interest in these things.

the best, as the moisture came late. Other years, especially with summer tilled land, early sorts like the Ohio will do better. Thus it pays to plant both early and late sorts to hit the season at one end or the other.

Summer Tilling and better early conditions will make better shape and better seed as well as increased yield. See under **Dry Land Potato Growing, and Julesburg 1910.**

YIELDS ON THE STATION PLOTS AT JULESBURG

Planted 14x38.

Stake	Variety and Source	Total	Ware	Culls	Stand
22	E. Ohio—boxed	10400	6200	4200	..
25	Triumph—boxed	7360	3840	3520	..
23	W. Ohio—boxed	5409	2254	3155	..
27	Cobbler—8 in.	12831	8554	4277	..
24	Cobbler—8 in.	10692	7026	3666	..
28	Cobbler—8 in.	10450	8250	2200	..
30	Perfection—8 in.	8250	5500	2750	..
3	Cobbler—Mancos	11100	9200	1900	..
4	Perfection—Maine	5600	4500	1100	..
1	N. Beauty—Maine	7900	6300	1600	..
2	Cobbler—Maine	11200	9600	1600	..
14	Pearl—3rd. yr. G.	9700	8300	1400	77
6	Ohio—Red River	9000	6500	2500	..
5	Ohio—2nd. yr. J.	10100	8000	2100	..
26	Pearl—boxed	6700	5600	1100	..
13	Pearl—2nd. yr. G.	9100	7200	1900	86
31	Pearl—2nd. yr. J.	9900	8400	1500	67
17	Pearl—Parshall	11300	9900	1400	84
19	Rural—Montrose	13100	11300	1800	..
12	Pearl—1st. yr. G.	11700	10200	1500	81
16	Pearl—Montrose	10100	8600	1500	70
15	Pearl—Stove P.	10000	8700	1300	80
18	Rural—1st. yr. G.	10800	9200	1600	..
20	Rural—Wisconsin	9800	8500	1300	..
9	Peachblow—Flagler	8700	6400	2300	..
10	Peachblow—8,000 ft.	8100	6100	2000	..
11	Peachblow—Carbondale	8700	6800	1900	..
7	Peachblow—Julesburg	7200	5900	1300	..
8	Peachblow—Greeley	8000	6400	1600	..

FORT MORGAN.

On June 9 we planted one acre at Fort Morgan with about 1/20 acre, one row, each of the following as a test of sources of seed potatoes of standard varieties for Fort Morgan:

Rural—Seed from four sources.

Pearl—Seed from ten sources.

Other Varieties—Three.

Grasshoppers practically destroyed the field. None of us realized how serious this pest would be here in 1910, or a long narrow field between grain and alfalfa would not have been chosen. A right good fight was put up when we realized the situation, but we could not have won unless we had had the special sprayer and arrangements used at Greeley.

Greeley Rules.—These will apply here, as to change of seed, deep cultivation, late planting, late watering, rapid harvest, as set forth elsewhere in this bulletin. In the vicinity of Brush heavy yields were secured, of excellent quality, both of Rurals and Pearls.

Varieties for Morgan County will be the Rural, Pearl, Ohio, and Cobbler. First year Greeley seed will do well, as will dry land seed which shows no signs of running out. Sage brush land potatoes from the mountains will do well, as will Wisconsin seed.

Morgan County dryland potato growers will find their problems discussed elsewhere herein.

GREELEY NOTES

All Yields at Greeley, especially of early potatoes were greatly reduced by serious shortage of water and holding it off too long early in the season. Water was so high in price that we could not require the rental of water extra to that normally sufficient.

The Largest Yields, in the order named were secured with Carmen

GREELEY YIELDS

Planted 15x38.

Stake	Variety and Source	Total	Ware	Culls	Stand
321	Rural—Divide, return	9810	7630	2180	72
322	Epicure—England	6750	5250	1500	80
323	Carmen I—Aroostook	16974	15744	1230	74
324	Pearl—Divide, return	13755	12838	917	..
325	Peachblow—8,000 ft.	10800	8800	2000	60
327	Carmen I—Penn.	11305	9282	2023	82
326	Abundance—England	10115	7735	2380	75
336	People—Carb.	10200	9400	800	83
337	Carmen III—1st. yr. G.	7000	5500	1500	87
338	People—Montrose	9500	8500	1000	70
339	Peachblow—Flagler	12400	10000	2400	77
341	Peachblow—Carb.	11900	9900	2000	75
340	Downing—Carb.	5500	3700	1800	88
330	Old's No. 116—Ohio	10920	9360	1560	90
334	Ninety-fold—England	7739	6540	1199	70
333	Banner—Red River	12102	10810	1292	90
328	B. Crawford—Ohio	13180	11680	1200	82
278	Pearl—1st. yr. G.	6700	4800	1900	..
348	Russet—Carb.	11900	10200	1700	92
349	Rural—Montrose	9300	8600	700	85
350	Rural—Del N. (big)	4200	3800	400	29
351	Rural—1st. yr. G.	6300	5700	600	81
331	Peachblow—Ohio	8000	6500	1500	82
332	Up to Date—Vermont	10865	9840	1025	66
335	Snowflake—Aroostook	9064	8038	1028	84
342	Pearl—Divide	13500	12200	1300	96
343	Pearl—S. P. (L)	9400	7900	1500	92
344	Pearl—Grover (N)	12800	11300	1500	90
345	Pearl—Grover (S)	14800	13300	1500	97
352	Snowflake—Stove P.	7000	6000	1000	45
353	Pearl—1st. yr. G. sod	12500	10700	1800	93
354	Carmen III—Plateau V.	10100	9300	800	86
346	People's—1st. yr. G.	7500	5700	1800	88
347	G. Mt.—1st. yr. G.	11600	9500	2100	97
355	Carmen III—P. V.	10000	9300	700	..
357	Carmen III—Wis.	15500	14000	1500	95
356	Carmen I—	11600	10600	1000	80
358	Pearl—1st. yr. G. (S)	12100	11000	1100	88
359	Prolific—Pagosa	13300	12400	900	75
360	Pearl—Montrose, G.	12000	10400	1600	97
361	Dewdrop—Maine	12100	11300	800	76
364	Pearl—S. P. (S)	10800	9800	1000	64
363	People—2nd. yr. G.	11800	10700	1100	86
362	Pearl—1st. yr. G. (D)	14300	12700	1600	89
365	Pearl—Limon (N)	16900	15100	1800	91
369	Pearl—S. P. (L)	14300	13400	900	74
370	Pearl—S. P. (L)	9400	8400	1000	48
371	Pearl—4 yr. Montrose	11900	10700	1200	85
372	Pearl—Wisconsin	13900	13100	800	68
	Same	14200	13000	1200	..
	Same	12800	11900	900	..
373	Pearl—S. P. (L, 8)	11600	10500	1100	..
	Same, 8.	13000	11900	1100	..
374	Pearl—S. P. 3x15	14600	13300	1300	..
366	Pearl—Parshall (W)	10900	10300	600	71
367	Pearl—Parshall (C)	13500	12500	1000	71
368	Pearl—S. P. (R)	8500	7900	600	51
380	Rural—Eaton	.....	.....	....	85
379	Rural—1st. yr. G. sod	11100	10200	900	78
378	Peerless—1st. yr. G.	10600	7900	2700	68
377	Pearl—Foothills (N)	11600	10000	1600	85
376	Peerless—1st. yr. sod	7700	6100	1600	60
375	Pearl—S. P. small (L)	11000	10300	700	68

I from Aroostook; Pearls from Limon, Colorado; Carmen III from Wisconsin; Green Mountains from Wisconsin; Pearls from near Grover; and Stove Prairie Pearls planted with three times the regular number of seed pieces (3 in each spoke). The Carmen I and the Green Mountain are of a shape unsuitable to Greeley conditions. The significant point is that no first year seed is in the first seven lots this year.

Close Planting of one lot of Cobblers increased the yield one third as did a double row of the same lot, while close planting of a first year Cobbler resulted in the lowest Cobbler yield. Close planting of Stove Prairie Pearl seed resulted in good yields at a cost for seed that would

GREELEY YIELDS
Planted 15x38.

Stake	Variety and Source	Total	Ware	Culls	Stand
241	B. Victor—Kimball	14200	12500	1700	92
243	B. Victor—Plateau V.	10900	9700	1200	85
242	B. Victor—P. Valley	.....	.....	....	73
244	Noroton—Maine	3600	2700	900	80
246	R. Seedling—Carb.	11600	9900	1700	89
245	E. Rose—Haxtun	11000	9700	1300	87
247	E. Ohio—Parshall	6000	5300	700	84
248	R. Seedling—S. P. (V)	5900	5700	200	58
249	Cobbler—Maine	4100	3400	700	73
250	Cobbler—Scotts Bluff	4500	3800	700	89
254	Same—double row	6100	4500	1600	89
253	Cobbler—S. B. 2x15	6000	4400	1600	84
251	Cobbler—Mancos	6600	5200	1400	86
252	Cobbler—Red River	6000	4800	1200	69
256	Cobbler—1st. yr. G. 2x15	3100	2100	1000	79
255	W. Ohio—Pagosa	4200	2700	1500	93
257	W. Ohio—Red River	3100	1800	1300	94
258	W. Ohio—Red River	3900	3000	900	87
259	E. Rose—Red River	9500	7900	1600	80
260	Six Weeks—Red River	4600	3600	1000	96
261	Thorburn's Early—	7740	6192	1548	80
262	Noroton—Sapinero	2992	1936	1056	93
263	E. Ohio—Sapinero	6698	4334	2364	93
264	E. Roser—Red River	6600	5300	1300	..
265	Triumph—Red River	4580	2748	1832	75
266	Cobbler—Akron	3658	2714	944	..
271	Bovee—Aroostook	7544	5576	1968	88
267	Cobbler—Aroostook	3825	2390	1435	98
268	Sunlight—Aroostook	4182	2706	1476	90
269	Perfection—Aroostook	5973	4525	1448	95
270	Dewdrop—Aroostook	7800	5980	1820	90
272	Noroton—Aroostook	.....	.....	....	50
273	E. Ohio—Aroostook	5713	4334	1379	98
274	Six Weeks—Aroostook	5900	4800	1200	87
275	Burpee—Aroostook	2900	1900	1000	100
287	Peachblow—Greeley	9400	7200	2200	..
286	Triumph—Boxed	7786	6412	1374	..
289	Rural—Boxed	11700	10200	1500	..
292	W. Peachblow—Boxed	12513	9288	3225	..
291	Pearl—Boxed	8930	6000	2930	..
290	Rural—Boxed	8316	6264	2052	..
276	"Pearl"—Maine	8200	6500	1700	86
277	Pearl—Del N.	11800	10700	1100	85
280	Pearl—1st. yr.	11000	9400	1600	94
283	Carmen III—Plateau V.	11300	10300	1000	78
284	G. Coin—Wis.	9700	8400	1300	79
279	Pearl—Carb.	12600	11400	1200	91
281	Pearl—Montrose, G.	9400	8000	1400	93
282	Pearl—Pagosa, G.	12500	11000	1500	87
293	G. Mt.—Wis.	15300	14000	1300	..
294	G. Mt. Jr.—Wis.	14900	13600	1300	88
295	E. Ohio—Wis.	5500	4300	1200	91
296	Thorburn's Early—	14178	12638	1540	94
297	State of Maine—Wis.	12204	10735	1469	85
302	Pat's Choice—Wis.	8500	7500	1000	45
314	Downing—Montrose	9180	7140	2040	75
315	Rural No. 2—Wis.	13800	13000	800	94
316	Carmen I—Maine	12528	10692	1836	91
318	Taft—Ohio	5848	5440	408	..
319	Snowflake—Ohio	7837	6462	1375	71

often pay. See Del Norte and Carbondale notes on close planting.

Other Points that may be cited are the promise of the Russet as a secondary early, borne out on the other plots: that Pearls first year Greeley from Montrose sage brush lands did as well as any Pearls the first year from dry land. This seed we have tried out for three years with the same result.

Changes of Pearl Seed.—All lots taken to the Divide, to Pagosa, to the plains, to the foothills, to Stove Prairie, when returned have this season done better than local seed. There is no exception save the one where run-out Greeley Pearls went to Montrose and returned. We find elsewhere that the tendency to run out may be held in check so far as yield is concerned, by changes, but will return at once, or after a season with ruinous results when the seed is brought back to the old conditions as often occurs with irrigated sod seed, at Greeley.

Stove Prairie seed continues to give good type and good yield per plant but very poor stands. We have shown that it paid **this season** to plant this seed thick in the row. Many tubers of seed size make up a good yield, although they appear small. We brought down in November 1909 several lots of Stove Prairie Pearls and had them carefully stored at Greeley. The stands were improved by this careful storage only five or ten per cent. During the winter of 1910 and 1911 we are securing Stove Prairie seed of different history to be tried in soils on hand from Fort Collins, Greeley, Del Norte, and Stove Prairie. Professor Sackett, our pathologist, has twice visited Stove Prairie with us to try to find some clue as to the cause of this rot. We regard this as one of the most important and most puzzling problems we have on hand.

SPRAYING FOR GRASSHOPPERS AND FLEA BEETLES

Bordeaux Mixture* applied with a twelve nozzle four row sprayer which covered the whole plant was used by Mr. Atkinson five times on the whole plot of four acres, and on the Atkinson, Badger and Emerson farms to test the great value of Bordeaux as a repellant to grasshoppers and flea beetles, as reported in Vermont and on Long Island. See **Potato Insects** herein.

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*Potato growers will find our arrangements at the Greeley plots for preparing Bordeaux mixture very convenient. A platform is required some six inches higher than the top of the strainer used on top of the spraying machine, and the water supply should discharge quickly into barrels standing on this platform. Four barrels are required: Two called **dilution barrels,** with hose attached to empty them into the 100 gallon tank of the spraying machine; while two barrels are used for **stock mixtures.** In one, 50 pounds of blue stone or copper sulphate suspended in a sack is dissolved in water and made up to fifty gallons. In another lime is water slaked in like proportions, one pound to the gallon. A box strainer with a bottom of common wire netting is then set over the dilution barrels, and into one with a gallon dipper made of galvanized iron, five gallons of the stock copper sulphate solution is poured out and made up with water to fifty gallons. Into the other barrel, after stirring well the stock solution of lime, five gallons containing five pounds of lime are strained and made up to fifty gallons. At this point equal quantities of each solution are put into a wide mouthed bottle and after being mixed by shaking, the mixture is tested with a drop of potassium ferrocyanide solution made from ten cents' worth of the drug. If a brown color results, the mixture will burn the leaves, and more lime from the stock barrel must be added to the dilution barrel until the test no longer shows brown. Then the two dilution barrels are emptied simultaneously into the sprayer strainer, the hose being regulated as to height so that the barrels empty evenly. Common blue stone costing about seven cents per pound in barrel lots, and the best of stone lime are used. Freshly slaked lime or that carefully covered with water and otherwise kept from the air is required. In some places lime contains magnesium impurities which are of no use in Bordeaux mixture.

ulletin 176. November, 1910

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

Productiveness and Degeneracy of the Irish Potato

Preliminary Studies Mostly Within the Pearl Variety

HYBRIDIZING

BY
C. L. FITCH

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1910

PLATE VI A FINE FIELD AT GREELEY.
An Intermediate Vine.

A PEARL TUBER: Part aerial, part underground.
A BLUE VICTOR "BASTARD" VINE: One plant between No. 4 and No. 5. Blossoms but no seed balls.

RODUCTIVENESS AND DEGENERACY OF THE IRISH POTATO.*

Preliminary Studies mostly within the Pearl Variety.

By C. L. Fitch, Potato Specialist.

There is every reason to believe that principles true of one variety ill be fundamental to all varieties of Irish potatoes. We submit these bservations, however, in their bearing upon one variety only.

Cause of Tuber Degeneracy.—We find that within the Pearl ariety, tubers become deep eyed, knotty, long and unproductive ecause of conditions that make the whole plant tend toward going o seed. Attention is called to the tendency of the tubers, which re enlarged stems, to be controlled in shape by the general habit of the lant. We also trace the branch and leaf habits which parallel tuber roductiveness and degeneracy, giving drawings of the typical charac-r of vines and corresponding photographs of tubers and using aerial ibers as proofs that certain tuber parts correspond to certain portions f other potato stems.

Sexual Tendencies.—We find the indicated factors of the tendency owards bearing seed to be early dryness, close and deep cultivation, nd disease. We find that tuber productiveness in Pearls is in-

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* The following is essential to the argument but not a part of it.

HE PEARL, PEOPLE'S, AND THE BLUE VICTOR, IDENTICAL EXCEPT IN COLOR.

The Pearl originated and still comes by bud variation from the Blue ictor. Of this family is the People's variety. All are alike in shape, xcellent keeping quality of the tubers, quick sturdy growth, and medium me of ripening.

The vines and leaves, branching habit and tuber arrangement are ike in the three sorts, with the exception of the darker color of the hole Blue Victor plant, as might be expected from the tuber color.

The differences in the tubers of the three sorts consist in color and e character of the outer skin. The Blue Victor is of a purple color hich, on exposure to the light, fades to a leaden brown, and is often reaked with white. This usually appears to be due to cracks in the skin, ut sometimes appears to be the real outside color by variation, and when covering an eye comes true in most cases both in the first propagation nd in the succeeding crops of Pearls. The Pearl is brownish white with, best, a well russeted skin, but there are often smooth spots on russeted earls, or whole crops that are nearly unrusseted. In the People's variety deeper brown characterizes even the unrusseted skin of tubers, and both e russeted and the smooth skin appear to be thicker. On all the three rts there are spots on occasional tubers, or more rarely whole tubers, hich resemble and are identical with each of the others,—including blue ots or blue potatoes from both the Pearl and the People's. The color ncentrated at the dormant sprout tips of the three sorts of tubers, at

versely proportionate to the sexual development of the plant; that the most degenerate tuber is grown by the plant which carries fully developed flowers and virile pollen; while those plants on which only the female portions of the flowers appear to be fully developed produce tubers intermediate in form and yield, and that the best tubers and the largest yield are produced by the type of plant whose buds do not even swell.

Practical Bearings.—The way is opened to study out:

1. What conditions insure productive seed potatoes.
2. How to grow potatoes free from defects.
3. What are the best changes of seed potatoes, and why.
4. How best, if way there be, to grow Pearl seed potatoes without change.

Additional light may be secured thereby on all problems of plant production where the seed is not the desired end.

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occasional stem nodes, and which tints the underground part of the main stems, is alike in the three sorts,—deep in the Blue Victor, and faintly pink in the others.

We go minutely into the characteristics of these three sorts because it is essential to our reasoning that the varieties are **one**, with **three** sorts of color; while the corresponding degrees of tuber degeneracy occur in the three colors and therefore cannot be confounded with the chance introduction of tubers of other varieties.

Alike, among the three varieties, we find the same ideal types, the same average tubers, and the same degenerate forms. With tubers Nos. 4 and 5 Plate IV, there is a change to a lighter color—a phenomenon not yet understood. In the Blue Victor, the "bastard" form is lighter pink than the others; among Pearls, the bastards are whiter and more waxy in color while in the People's variety, the bastard forms, when placed beside Pearl bastards show the deeper brown shade that is a characteristic difference betwen the varieties.

The term **bastard** is one employed by growers and is herein used to mean a certain degenerate form of tuber of the Pearl family.

Environment of Plants Observed.—The writer has had experimental plots at elevations of 3500, 4000, 4500, 4800, 6500, 7000, 7800,, and 8100 feet and on soils ranging from light sand to clay loam, and with fertility varying from the limited nitrogen and humus content of lands never yet deeply moistened by nature and supporting only scant buffalo grass or scantier sage brush, to that of irrigated alfalfa lands perhaps unexcelled in natural fertility and nitrogen content. See Bulletin 175 of this station for a discussion of **The Potato Industry of Colorado.**

The Solution of a Leading Problem of one of the most highly specialized of farming communities is herein sought for the sake of that community and of the potato industry. The study is founded upon the previous work of the Station and is an out-growth of that spirit at Greeley which makes potatoes and the intricate problems of potato growing the leading topic wherever farmers get together, whether at the open meetings of the women's country clubs, or when neighbors talk over the fence in the field.

Other Names: Of the Pearl.—Peerless, White Victor, Valley Prize, Mammoth White Pearl, and, in the opinion of Sutton & Sons, the Puritan, of Great Britain. **Of the Peoples**—Polaris, People's Party.

Future Development Work.—The way is pointed to explanations f the indicated superiority of seed potatoes grown under mulch and f those dug as in England before they are ripe. The promise of the uture is that conditions favor the production in the Rocky Mountain egion of the new varieties of the future, because on the arid irri- ated plains the plants may be made sexual at will, be crossed, and ıen be developed under ideal irrigation conditions in our mountains. mprovement in varieties, which normally have a greater sexual de-

PLATE II. AN IDEAL HILL OF PEARLS.
Without Compound Eyes, Deep Eyes or Knots.

elopment than prolific Pearls, will doubtless be found in the selection f those plants and tubers which are the most completely asexual in abit.

N OUTLINE OF THE OBSERVATIONS ON WHICH THE FOREGOING IS BASED.

The Pearl Potato and the Pearl Seed Supply.—The Pearl is ıedium in time of maturity, and is better adapted to most regions f Colorado than any other sort. It is a great surface feeder and is dapted to soils made shallow by underlying moisture or gravel. It is good keeper, and its vines are little subject to attacks by *Fusarium,*

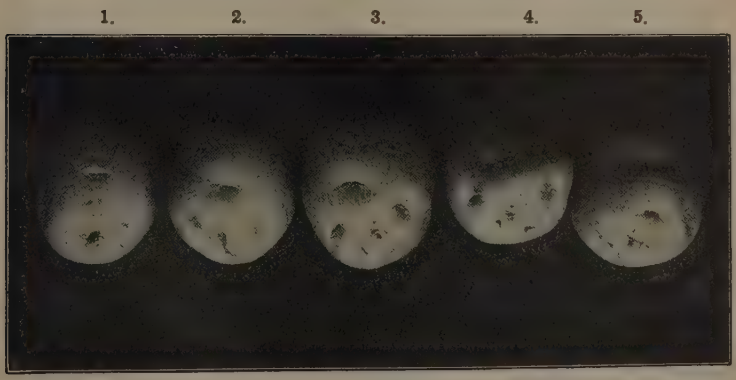
PLATE III. PEARL BASTARD: SEED BEARING PARTS.
Drawings by Miriam A. Palmer.

or its tuber to dry rot. The quality is excellent under good conditions.

Those regions which find Pearls their best variety are unable to maintain Pearl yield or shape, and are compelled to buy seed from other regions every year for raising the seed tubers to plant the large fields for the following year. Greeley also finds the Pearl variety subject to knots. In fact the most pressing economic need for the potato industry of Colorado is the increase and betterment of the Pearl seed supply.

Pearl Vines, Tubers and Blossoms.—The most productive Pearl vine (No. 1, Plate III.) stands, not erect in any of its parts, nor yet prostrate, and is typical of good conditions and good yields of tubers, free from knots and from deep or compound eyes. Where subjected to early drouth and close deep cultivation (No. 2) and then given abundant moisture, the main stems grow longer and interfere with the running of water as they become prostrate from the weight of "risers" which grow straight up from the nodes. The tubers produced by this common type of vine, while usually good, have deeper eye pits

PLATE IV. COMMERCIAL PEARL SEED.



and more bulging eyes, and are subject to knots. About September 1st good fields of No. 2 look like alfalfa fields, the growth is so rank and the surface of the field so even. Such a field is shown in the photograph, behind the irrigator, with a single No. 3 vine in front of the coat. Plate VI.,page 2.

This type (No. 3) marks the change from value to worthlessness. Fields that are rough and ragged over the top from the presence of No. 3 and No. 4 are undesirable as a source of seed. These vines are much alike, except that No. 3 divides the top. The blossom of No. 4 is more developed, and its tuber shows sudden and great degen-

eracy. Both No. 3 and No. 4 have been found only as single plants in the hill, which peculiarity may be attributed to strong tendency in the seed piece to grow single stalks and no side branches at the eye. No. 5 bears fertile pollen and large fruits with many vigorous seeds. It has more than one plant to the hill and loses the strong central character, but all the branches are erect, while the tuber becomes a pear shaped degenerate. There are of course forms intermediate between these types, but as a whole the steps are surprisingly distinct.

Pearl intermediates and bastards are found in the crop from the same seed which under better conditions produces only Nos. 1 and 2. For instance, a lot of Pearl seed, grading No. 2, from Del Norte, produced at Carbondale, in 1910, no intermediates or bastards, while the same lot of seed under the degenerating conditions of 1910 at Greeley produced many of both intermediates and bastards. We have found the same true with us time after time from seed sorted and restored, tuber by tuber by experts.

Sexual Tendencies Stronger than Selection in the Greeley district. The writer for four seasons, commencing with 1905, practiced near Greeley hill selection* of seed potatoes. In 1908 he selected from hand dug hills in the field a carload of seed Pearls and in 1906 a half carload. The tubers kept good in shape, even improved in outline, though the eyes were a little deep, and the reduced yields were ascribed to seasonal and other causes. The main stems became gradually stiffer. After the fall frosts the "first year" vines were prostrate, their leaves in the ditches, and the stems showed white as they lay on the hill, while the "pedigreed" vines had stiff upright center stalks which carried a brown flag of frosted leaves. The fields could thus be told apart to the row by their color as far as they could be seen. In 1909, on the same farm, because, it seems, the seed-bearing tendency had accumulated to override all other influences, the type and yield gave way to long cylindrical and irregular shapes with many bastards and seed balls. These Pearls in 1909 did very well at Pagosa and at Montrose and fairly well on the college plots, but, in 1910, from all these sources, on our various plots, and at Pagosa and Montrose, in private hands, showed their degeneracy of vine, tuber and yield. We have noted at Carbondale the gradual improvement of Pearls and other varieties long grown under ideal conditions, as compared with the type of Pearls more recently brought from places where they had approached the intermediate form.

Blossoming of Pearls.—Neither the Blue Victor, the Pearl, nor the People's when at its best blossoms at all. The buds form early on relatively obscure stalks, but do not swell, do not show any color besides green, and soon blast and break off. This is true of vine No. 1, and to a large extent of vine No. 2, which last is characteristic of the Greeley district. Vine No. 2 will sometimes show color in the buds before they fall, and adverse conditions may produce late buds of this sort on No. 1; while severe dry early conditions will incline the habit of No. 2 in August strongly toward that of No. 3, and late bloom will be

profuse. The blossoms of No. 3 are usually abundant, and while the female parts appear to be well developed the stamens are incompletely developed, and do not bear pollen. No. 4 is like No. 3, but with greater sexual development and a marked approach of the tuber toward that of No. 5, which bears abundant large seed-balls, with many and vigorous seeds.

PLATE V. PEARL BLOSSOMS.

Drawing by Miriam A. Palmer.

Intermediate Forms have a greenish yellow stamen, sometimes replaced by a hair, and always lacking in shape, color and pollen. No. 3 vine.

No. 5 Vine bears fertile blossoms with full corollas and orange colored stamens, with abundant virile pollen.

Conditions at Greeley.—The soil in this region, when well rotated with alfalfa, and especially when manured for a series of rotations, is exceedingly fertile, so that there are farms on which for years a yield of forty bushels of wheat per acre has been the minimum and where sixty bushels has been exceeded. As in most of the upper plains regions, there is a large element of adobe or gummy clay present in the major part of the soils of this district; and even when a part of sandy friable loams, this gummy ingredient is an adverse factor in the growing of potatoes, especially under irrigation on lands rather too flat* for water to run without puddling the sides of potato hills. Thus, with conditions favoring soil diseases of the potato, it has been proven by long experience at Greeley that on the average farm very close and very deep cultivation is the most profitable. The region and its people co-operate well and this system when once worked out has been applied to all lands alike, even where greater slope and more open soil make so rigid a system less desirable.

*See in Bulletin 175, **Irrigation, Potato Diseases and Cultivation.**

To make the best use of water and to delay air exclusion, if possible until the cooler weather of late July and August, irrigation is put off until the plants show considerable signs of suffering for water, or until in most cases after the first blossoms have opened and the tubers set. In most seasons there is moisture about the lower roots sufficient to sustain the plants, but as no rains come, there is not moisture enough above the seed piece, and no tubers are set until well into August, because tuber stems do not start unless moisture is in actual contact with the main stems. This is the chief reason for hilling potatoes—to more thoroughly mulch the soil about the main stems, and is said to have been discovered in Germany in the early days of potato culture there. It is one of the basic principles of potato growing.

Thus in the Greeley system the deep close cultivation tears off side roots, dries out the soil, and reduces the food supply at and prior to blossoming time. A well known scientific law which applies both to animals and as here to plants has been formulated by Doctor J. C. Arthur of Purdue University as follows: "A decrease of nutrition during the period of growth of an organism favors the development of the reproductive parts at the expense of the vegetative parts." With this fact all the farmers are familiar in its application to farm animals, and, in Colorado, growers of wheat and of alfalfa for seed production know that the withholding of water at a certain stage of growth increases the set of seed.

Associated at Greeley with methods that reduce the supply of available food at the budding and blossoming season, we have an unnatural delay of tuber formation, and the use of food therefore, followed, when irrigation at last commences, by the instant availability of a large food supply. Thus we have all the requisites for variation* of the plant in all its parts at the time of tuber growth in the direction of any impulse given it by previous conditions. Disease is also a large factor, often the largest factor, in potato plants tending toward going to seed. Often when the underground stems and tuber stems are attacked, especially in rich conditions, by fungous disease, there is induced a trouble called in Colorado "Little Potatoes." The prominent symptoms of this disease are the growth of large vines and many and large side branches, and the formation above or just below the ground of many small knotty tubers. These side branches blossom profusely, even when grown from tubers borne by prolific non-blossoming plants, but do not appear, the first season, to bear pollen.

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*Abundant food supply is recognized by plant breeders as promoting or allowing variation, reversion, or "sporting;" and wild plants are considered to be more stable and uniform in their characteristics because struggling in nature with other plants for food, they are less richly nourished than when cultivated by man and thus favored, protected and allowed to develop freely their inherent qualities.

Professor Alvin Keyser cites the work of Professor E. G. Montgomery, which affords a somewhat parallel phenomenon with Indian corn. About fourteen nodes are typical of the corn stalk, the upper seven of which are long and may develop tassels or male flowers, while the lower seven have power to develop female flowers and ears of corn. Normally one or two ears are formed and at upper nodes of the lower seven, but in the case of accident or removal of the ears naturally developing, ears may be formed at other nodes, and experimentally it has been found possible to induce the development of ears at all of the nodes.

The Influence of Nitrogen.—"Speaking generally, excessive food supply leads to infertility among both plants and animals. The former vegetate luxuriantly, but they do not blossom and fruit so abundantly as under a full but moderate supply of plant food." We were justified in making the assertion "that extreme proportions of nitrogen produce luxuriance in stem and leaf at the expense of flower and fruit."* Potatoes need rich conditions to continue productive vegetative growth. Experimentally and in commercial practice we find that seed potatoes grown from good stock and under good early conditions of moisture and health, but with only a moderate amount of plant food, on our buffalo sod or sage brush ground,† expand into remarkabe vegetative and tuber growth when planted on our rich alfalfa lands, are most nearly asexual in habit, and have the finest tubers the first year, with usually the largest production the second season.

Change of Soil.—Change from one region to another, or from one farm to a different but not richer soil, affords a change of food which is also a stimulus to potatoes and retards sexual development, thus maintaining to a degree good tuber shape. We find, however, that constant change may hold in suspension for several years the tendency to seed bearing and tuber degeneracy, which may then come suddenly, on return to less favorable conditions, or on being grown for a second year on the same ground.

Identity of Tuber Parts.—Aerial tubers give the best proof of the morphology of tuber parts. Plate VII is a Pearl plant from which the tubers were removed by hand in 1910 at Del Norte. In this case the plant not only enlarged upper branches, many of which formed into tubers, but also enlarged the main stem with normal potato-tuber tissue. In Plate VI, page 2, note a Pearl tuber also from Del Norte in 1910, the result of disease. One portion of the tuber was grown above ground and one below. These tubers show that the eye yoke is the laying of the leaf onto the stem; that the yoke point is the remnant of the leaf stalk base; that the sprout tips are the ends of leaves later to be followed by the sprouts; that knots are swelled, protruding branches of tubers; and that "compound" eyes are but lesser knots. The emphasis of the yoke on aerial tubers is quite like the dif-

* E. Davenport in Principles of Breeding, 1907, page 226.

† To a less degree this is true of seed potatoes grown upon pea stubble.

ference of main stems below the ground and above. Below ground the stems are smooth, while above ground potato stems are squared by successive leaves whose bases spring from the stem. In Pearl bastard seedlings, which are strongly sexual, the stems are squared—even winged by the leaf stems.

PLATE VII.
Pearl Aerial and Main Stem Tubers.
The result of removing natural tubers.

Color and Degeneracy.—With the old Peachblow, and with Pat's Choice and other varieties, the pink color follows the yoke lines, and strong color seems associated with sexual or degenerate tubers. With Ohios and improved Peachblows, the better the conditions the lighter the color of the tuber, and the worse the conditions and the type, the deeper the red color the heavier the yokes and the deeper the eye pits or the more protruding the eyes. With Ohios, knots and seed ends are often of color diverse from that of the main tuber, or of other knots, possibly from varying influences during growth. Similarly, we often note different types on the same tuber, and we have a photograph of a Cobbler tuber, which is long, and in three sections—the first round, the second elongated, and the third a true Cobbler again. Peachblow tubers often project the main stem forward with all the end eyes and form either a new tuber or an end knot, usually of a darker red color.

HYBRIDIZING.

The Pearl is one of our healthiest varieties, is medium early and a heavy cropper. If in a large selection of hybrids with the Rural we could find one plant which retained the desirable qualities of the Pearl with somewhat more of the balance and smoothness of the Rural tuber, the value to the Colorado industry would be great. At Del Norte, in 1910, Francis Chisholm made sixty-seven crosses both ways between the two varieties. Twenty-five seed balls were secured but a hail storm

reduced the number to seven. One of these was of Rural pollen on Pearl and contained no seeds. The six of Pearl pollen onto Rural all bore abundant seeds. We judge incomplete fertilization characteristic in Colorado of Rural pollen and of the pollen from the Early Rose family as we cut open 650 seed balls of these sorts and found no seeds.

Next to the improvement of the Pearl, the most important work of this kind in Colorado is the introduction of some more disease resistent factor into both vines and tubers of the Rural family, and this result may be obtained in connection with the improvement of the Pearl.

A third object is the securing of a better early variety than the Ohio or the Cobbler. If the desirable qualities of these two varieties can be combined, the benefit will be very great to all who grow or who eat potatoes.

Our experience indicates that the crossing of varieties can be done with the best success at Greeley and Del Norte, and that selection and development is likely to be most successful at Carbondale. We find also that the best conditions for final seed potato production are likely to be those of the dry regions of Northeastern Colorado or of the Arkansas divide, and of high sage brush lands under ditch.

It is calculated that if Pearls can be made to run smooth and not knotty, and Rurals made more healthy and a little earlier, that the Colorado crop will average to be worth at least five per cent. more money. Such improvements should be accompanied by at least an equal gain in yield, as herein foreshadowed, so that we may expect such work if eventually successful to increase the returns from potato growing at least ten per cent. in Colorado. This percentage on our crop is already $600,000 per year.

BALANCE: A NEW TERM DEFINED.

Balance may be here defined as the proper relative growth of the main stem, branches, and leaves and the proper relative influence indicated by aerial tubers to be exercised by each upon the shape of tubers formed by the swelling of underground stems. Eyes are shallow when the leaves and branches are in balance each with the other, and affect the surface of the potato equally. With such potato vines as have strongly sexual main stems tending to become seed stalks, the branches of the main stem are relatively weak and short while the leaves and the leaf stalks are very strong so that the main stem is crooked and takes an altered direction from every point of division from the leaf stalks. In the tubers borne by such plants, the leaf yokes are very prominent and the bottom of the eyes, which are the tips of the branches or sprouts, are receding, thus forming deep eyes. In such tubers in most cases the number of branches and the number of leaves includeed within the tuber are increased so that the tuber is relatively long with many and deep eyes. The formation of such tubers from stems whose counterparts above ground bear many short branches and many stiff

leaf stalks growing from a stem of elongated character may be conceived to account for such tubers being circular rather than elliptical in cross section. The better the balance of tubers the flatter they are and the more run out the more nearly circular their cross sections.

Strong side branches and the tendency of branches to turn upward appear to be coordinated with tubers being flattened, as are all our sorts to some degree when most productive, and with the fact that most of the eyes of such tubers are on the upper side. When first formed, such tubers are not flattened, the Rural for instance being, when newly formed, circular in cross section, and later flattened.*

Aside from the above stated element of proper balance in potato plants, there is another element of balance, the tendency of stems either to stop growth before the tuber growth ceases, or to go ahead of the growth of tuber parts and tissue. The improved Peachblow potato is perhaps the best example of this. It has in many cases a recessed seed end, and in many cases it renews growth from this end, forming, especially with seedlings, which are more sexual, a series or even a "necklace" of tubers on one stem. In this variety also there is a noticeable tendency for growth to start from within the tuber, possibly from dormant buds. Large tubers of this variety crack very seriously and within the cracks are found what appear to be internal tubers or knots bearing eyes like those on the exterior surface of the original tuber. When flattened, large Peachblows seldom crack.

The element of balance shows in Pearls in another way namely that tuber stems of more strongly sexual plants are more subject to the tendency of the branches to grow and form knots. Growers commonly say that uneven watering occasions knots, and they are undoubtedly right, except that the tendency of previous years is perhaps a more important factor.

HARMONY OF PLANS FOR POTATO BETTERMENT.

It is a great satisfaction to feel the entire harmony of objects sought in potato breeding. Within the bounds of a variety the largest yields, the most desirable flattened tubers, and the shallowest eyes, go together. Conditions that favor one of these qualities favor the others. The largest profits to growers, and best quality for the housekeeper come from the same fields. Undesirable cylindrical shape, undue length of tuber, bulging or "compound" eyes, knots, deep eyes, and irregular shape, altho affected by varietal differences, appear to have common causes and common remedies.

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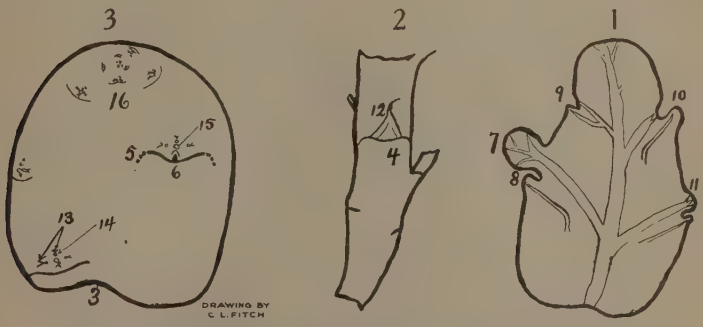
*Flattened seed tubers, other things being equal, may be expected to be most productive. We have noted this with Snowflakes and have found the Russet to be quick to respond to selection of wide seed tubers. At Carbondale, in 1910, we obtained from wide seed Russets 6,257 pounds per acre more than from slender round tubers of the same stock.

TUBER PARTS NAMED.

This plate is prepared to make clear the definitions herein given of tuber parts and defects. The plate is numbered from 1 to 16, as below explained.



TUBER NOMENCLATURE; PLATE VIII.

1. Longitudinal section of a tuber with defects.
2. A portion of the main stem of a potato plant.
3. A Pearl tuber with *recessed stem end.*
4. *Leaf Yoke* or line of separation of the leaf from the stem and corresponding to the eye yoke at No. 5.
5. *The Eye Yoke* on a good tuber has only the central portion On degenerate tubers, it is stronger, and on aerial tubers runs down at the ends as indicated by the dotted line at 5.
6. *The Yoke Point* is absent on the best tubers but is strong on the sexual tuber shown on Plate VI, page 2. No. 6 corresponds to No. 12, the stub of the leaf stalk.
7. *A Knot* or protruding tubered branch, accompanied by a deep eye pit.
8. The *eye pit* is here deep.
9. A deep eye *pit* without a knot.
10. A heavy *eye brow* and a deep eye pit.
11. A *compound eye* and a deep eye pit.
12. The *stub* of a leaf stalk, corresponds to No. 6, the *yoke point.*
13. *Eye blinds* are little bracts just *outside* the sprout tips.
14. A *side sprout* tip.
15. A *main sprout* tip.
16. The group of eyes here suggests the growers' name, *seed end.*

GOOD PEARL SEED POTATOES: TEN RULES.

Founded upon the foregoing or explained thereby.

PEARL SEED IS BEST TO BE:

1. From a field free from bloom and the ragged appearance produced by the presence of many vines of types Nos. 3 and 4
2. Of true Pearl shape without yoke points or deep eye pits, and with the fewest possible knots and compound eyes.
3. From dry land sod or high altitude irrigated sage brush lands with plenty of slope.
4. Brought from less to more fertile lands—not the reverse.
5. Exchanged between farms of the same region, rather than kept on the same farm.
6. Not from land where, if soil diseases are a factor, the crop was grown after potatoes.
7. From fields watered early, where slope and temperature allow this to be done without causing disease.
8. If from above the ditch, from summer fallowed lands planted rather deeply.
9. From fields which produced a good yield of medium sized tubers, and did not run too large, because in the latter case the tubers of seed size are apt to come from the weaker hills.
10. From special seed patches planted close, and perhaps dug early.

CHANGE OF PLACE OR SOIL is not the whole problem.
THE TYPE OF THE TUBER does not answer all our questions.
AT LEAST THREE YEARS HISTORY of the stock is necessary.

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The Agricultural Experiment Station
OF THE
Colorado Agricultural College

HOLD-OVER BLIGHT IN THE PEAR

BY

WALTER G. SACKETT

PUBLISHED BY THE EXPERIMENT STATION
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1911

HOLD-OVER BLIGHT IN THE PEAR

BY WALTER G. SACKETT

There seems to be some difference of opinion among the fruit growers in this state as to whether the microorganisms which produce fire blight in the pear, apple, quince and apricot can live through the winter in the diseased limbs, twigs and fruit of the previous season under Colorado conditions and still retain their virulence in a degree sufficient to start off a new attack in the spring. Practically all agree that the hold-over form of the malady exists in the old cankers of the trunks, such as are found in the Ben Davis tree, and most of them are familiar with the characteristic oozing of the sticky gummy material in the spring, but the disagreement which has arisen has been concerning its persistence in the smaller limbs and twigs.

On the one hand, if the germs can survive the cold weather and the drying, then there is the greatest necessity for thorough inspection and careful removal and destruction of every infected portion of the tree before any new growth begins; on the other hand, if the causal organisms are destroyed by natural agents, there could be a big saving of labor at the time of the year when the orchardist's services are in demand for the routine pruning. He would not feel the urgent need of cutting out the blighted wood before doing anything else, and could postpone this to a more opportune time. Furthermore, the usual precautions to disinfect the tools and freshly cut surfaces, when working in blighted material, would be unnecessary, and there would be no objection to removing the diseased limbs while the general pruning was being done, so far as spreading the contagion is concerned.

It is not at all uncommon to find in the literature on this subject such statements as the following: "the germs gradually die, due to drying out of the canker so that at the beginning of the dormant season *very few** such cases show live germs present;" "The key to the whole situation is found in those cases of active blight *(comparatively few)* which hold over"; "These *few* cankers in which the bacteria survive the winter are called 'hold-over' cankers." The writer is likewise guilty of having made a similar statement in a former publication, not upon its own authority however, but from information furnished him by a well known horticulturalist, familiar with Colorado conditions. Everywhere the tendency has been to underestimate the prevalence of hold-over blight, in spite of the recognized fact that were it not for this form of the disease, blight could not be carried from one season to another.

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* Italics by author.

Inasmuch as there was no first hand information available on this subject for the higher altitudes, based upon actual laboratory examinations, the writer has undertaken a study of Hold-over Blight as it occurs in the arid climates, with the hope of adding something to our present knowledge, as well as obtaining more exact data than the well meant but too often unreliable facts given by casual observers. It seemed to me that if unfavorable conditions for the survival of bacteria existed anywhere, they should be found here, in Colorado. The dry winter winds, which often blow for days at a time, are notorious for their destruction of vegetation; the sun shines almost continually throughout the winter months and the temperature often falls as low as —16° F. to —22° F. It would be difficult, indeed, to find natural agents more inimical to microbic life than drying and direct sunlight combined with the possible injury by low temperatures.

The investigation was begun in the summer of 1909, and has been carried on through the winters of 1909-1910 and 1910-1911. In order that we might have hold-over material with which to work which we knew contained the living germs in an active condition during the growing season, we visited certain orchards in the summer time where the blight was in progress and tagged a number of small limbs and twigs varying in size from 1 m.m. to 40 m.m. (3-8 to 1 1-2 in.) in which the blight was unquestionably present. Material from five different orchards has been examined. These orchards, scattered over a wide area, present climatic conditions representative of practically 2000 square miles of fruit land on the Western Slope.

METHODS

Since it has been shown that the bacteria in the hold-over cankers are usually found in the zone just next to the living tissue, we always made it a point, when collecting the specimens to take such sections of the limbs as would include the lower boundary of the blighted, discolored area together with a few inches of the adjacent live wood.

Immediately befor making our isolations, each specimen was wiped thoroughly with a 1-1000 solution of mercuric chloride which was allowed to dry on the surface. This precaution was taken in order to eliminate as far as possible exterior contaminations.

The outer bark was removed with a scalpel, sterilized by boiling, and with a second sterilized scalpel, a diagonal cut was made just above the junction of the blighted and healthy areas, through the cambium into the wood so as to include portions of both the diseased and healthy cambium. Small pieces of both the blackened and normal cambium were removed with aseptic precautions, and dilution plates were made from this material in nutrient agar, +15° Fullers Scale. The plates were kept at 20° C. and after four days, the characteristic Bacillus amylovorus colonies were isolated onto agar slants. In addition to verifying the cultures as B. amylovorus by cultural and

biochemical methods, they were all inoculated into pear seedlings in order to determine their virulence.

EXAMINATION OF MATERIAL.

The first collection of hold-over blight material, tagged during the summer of 1909, was made Feb. 28, 1910. At this time twenty-one specimens were obtained representing three different orchards. From

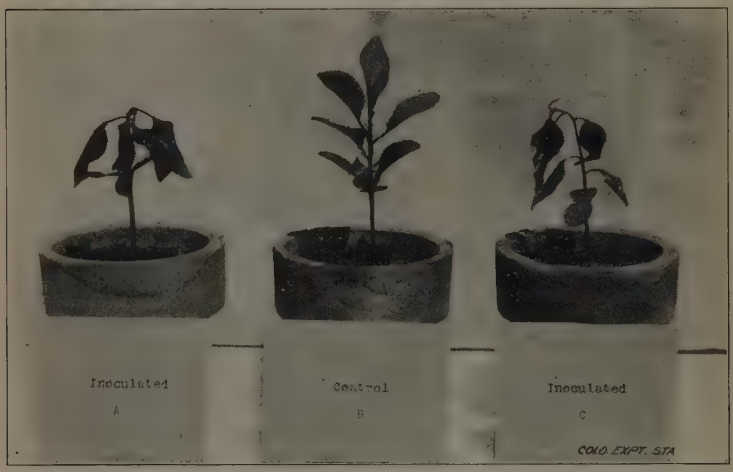

Fig. 1. A and C. Two pear seedlings five days after being inoculated with cultures of B. amylovorus isolated from hold-over canker April 21, 1911.

Fig. 2. Hold-over canker on pear twig showing characteristic cracking from which the oozing takes place.

seven of these, or 33.33 per cent, cultures of B. amylovorus were obtained. Three of the limbs were between one, and two and one-half

inches in diameter, and none contained living germs of blight. Ten of the samples varied in diameter from one-half to one inch, and the remaining four were water sprouts. The seven positive cases all occurred in the branches having a diameter of one-half to one inch, and four of these were small yearling twigs of 1909 growth. Only one series was examined for the season of 1909-1910.

On Jan. 26 and 27, 1911, the first collection for the 1910-1911 series was made. The winter was regarded locally as open with considerable snow and rain. At this time twenty-eight samples were secured representing three orchards, two of which were different from those used during 1909-1910. Virulent cultures of Bacillus amylovorus were obtained from six or 21.43 per cent. of these twenty-eight branches, and when 48 hr. cultures of the microorganisms isolated were introduced by needle pricks into the growing tips of pear seedlings, one culture produced typical blackening in four days, two in five days and three in eight days.

The second series was gathered from the same orchards April 12 and 14, 1911. In one of the orchards, the peaches, apricots, cherries and plums were in full bloom. The pear buds had burst but the blossoms were showing no color. Apple buds were swelling. No oozing was observed from the blight cankers. In another orchard, the peaches, apricots and pears were in full bloom; the cherries and plums had already shed their blossoms. Apples were just beginning to show color. No oozing was visible. In the third orchard, peaches and apricots were in bloom, apple buds were about to burst, and the pear buds had opened but were showing no color in the blossoms. There was abundant oozing from the blight cankers on the larger limbs. In all, thirty-four branches and twigs were obtained, twenty-four of which came from the third orchard. The isolations were made April 21 and 22, and of the total number examined in this series, eight or 23.53 per cent. yielded virulent cultures of the blight organism. Five of these produced typical blackening of the pear seedlings in seven days, two in eight days and one in sixteen days.

The following table, No. 1, may be of interest in showing the relation between the occurrence of B. amylovorus and the size of the twig, as well as the character of the microbic flora in the blighted area.

Relation between size of twig and occurrence of B. amylovorus. Material collected April 12, 14, 1911.

(Table No. 1.)

Sample No.	Diameter of twig in millimeters	Presence of B. amylovorus	Character of microbic flora found in blighted wood.
1	12	—	Moulds
2	13	+	Pure culture B. amylovorus
3	16	—	Sterile
4	13	—	Mixed, cream and yellow colonies
5	13	+	Pure culture B. amylovorus
6	10	—	Sterile.
7	14	—	Fluorescent green colonies
8	12	—	Fluorescent green colonies
9	7	—	Sterile.
10	9	+	Mixed, B. amylovorus
11	10	—	Moulds.
12	7	+	Pure culture B. amylovorus
13	12	+	Pure culture B. amylovorus
14	13	+	Pure culture B. amylovorus
51	17	—	Moulds.
16	16	—	Moulds.
17	12	—	Moulds.
18	14	—	Moulds; cream and yellow colonies. No. B. amylovorus.
19	15	+	Pure culture B. amylovorus
20	14	—	Moulds.
21	16	—	Sterile.
22	23	—	Mixed; yellow, green and white colonies
23	30	—	Cream colonies
24	21	—	Moulds
25	23	—	Mixed; yellow and white colonies, moulds
26	47	—	Pale cream colonies
27	36	—	Yellow colonies and moulds
28	30	+	Pure culture B. amylovorus.
29	28	—	Yellow colonies
30	28	—	White stellate colonies
31	38	—	Sterile
32	20	—	Moulds
33	26	—	Sterile
34	23	—	Sterile

Table No. 2 gives the summary of the results of the two years' observations.

Summary of Hold-Over Blight Determinations.
1909-1911.

(Table No. 2.)

Date of Collection	Date of Examination	No. of Twigs Examined	No. containing living B. amylovorus	Per cent containing living B. amylovorus
Feb. 28, 1910	Mar. 4, 1910.	21	7	33.33
Jan. 26, 27. 1911	Feb. 4, 1911.	28	6	21.43
April 2, 4, 1911	Apr. 21, 22, 1911	34	8	23.53

Total number twigs examined, 83.
Total number twigs containing living B. amylovorus, 21.
Total per cent twigs containing living B. amylovorus, 25.3.

Closeley related to the question in hand, is the persistence of the blight organism in the pruned twigs. We have always advocated and insisted upon the prompt collection and early destruction of this material because of the supposed danger of the disease being carried to the healthy parts of the tree. Through the courtesy of Prof. H. R. Fulton of the Pennsylvania Experiment Station, I am permitted to give here the results of his recent investigation along this line. While his work has been carried on in Pennsylvania, it is only reasonable to believe that, here again, the dry climate of Colorado would be even more severe upon the bacteria than the moist conditions which prevail in the East.

"Twigs in which the blight bacillus seemed to be actively spreading were selected. These were cut in the ordinary way, and allowed to lie on the ground in thick clover and grass sod during the process of each test. The indication of viability of the organism in each instance was taken to be the inducement of characteristic blighting of succulent twig growth of apple, following its inoculation with bits of inner bark tissue from the tested twigs. These bits of bark were removed with sterilized instruments from three points in the region most recently invaded by the bacteria. They were introduced separately under the young bark of the rapidly growing twigs; and the incisions were covered with paraffin. Such a test was made first of all on the day the tested twigs were cut, in order to be sure of the viability of the organism at the outset. Subsequent tests to determine the time of its persistence were made in the same way after three days, five days, seven days, and in a few instances after a longer period."

"Out of a total of 35 twigs containing viable *Bacillus amylovorus* when cut, thirty-one twigs, or about 9-10 did not contain living bacteria at the end of a week; and most of these became inactive in three to five days. The death of *Bacillus amylovorus* in the twigs was rather uniform in the different tests, and there was not apparent such differ-

ences in the persistenc as might have been expected from the difference in rapidity of drying of the twigs. There was indication of slightly longer persistence in the last two tests when lower temperature was a more conspicuous feature perhaps than increased moisture. Twigs that had been blighted for a longer period did not show any difference in persistence from those of shorter period, the test in each instance being made from portions of the bark recently invaded.

Incidentally it was noted that the dried distal parts of blighted twigs did not, as a rule contain viable blight bacteria. The extent of the zone containing them was not determined, but it evidently varied, and included in general the discolored bark that was apparently moist. The characteristic dried exudation made up of blight bacteria, was tested in several instances, and the bacteria in this seemed regularly to remain alive longer than in adjacent dried bark; and their persistence after the twigs were cut was two to four days longer than of bacteria in recently invaded bark of the same twig.

When one considers the comparatively rapid death of blight bacteria in cut twigs left on the ground, which these tests indicate, and the unlikelihood of any ready transfer of infective material from such a situation to living parts of orchard trees, one is inclined to question the necessity for rigid destruction of cut off twigs. It may, however, be well to defer final judgment until the effect of leaving such material on the ground, has been observed in actual orchard practice."

CONCLUSIONS.

1. In the arid Western climate, the prevalence of Hold-over Blight in the small limbs and twigs of the pear has been underestimated.

2. Under Colorado conditions, at least 20 per cent. of hold-over cankers on the small limbs and twigs contain virulent blight organisms at the time of blossoming.

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THE FIXATION OF NITROGEN

IN SOME COLORADO SOILS

A Further Study

BY

WM. P. HEADDEN

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THE FIXATION OF NITROGEN IN SOME COLORADO SOILS

A Further Study

By WM. P. HEADDEN

INTRODUCTION.

In Bulletin 155, of this station, I endeavored to demonstrate the occurrence of large quantities of nitrates in some of our Colorado soils by giving a number of analyses showing the presence of phenomenal quantities of these salts. So far as I have been able to learn it will undoubtedly be wise to lay emphasis upon this fact as its importance is fundamental; therefore, I shall give further examples of this occurrence though it seems that it ought to be a superfluous task.

A second point which I endeavored to make perfectly plain was that I was writing not only of an extreme degree of concentration of nitrates in the soil but that this concentration pertained to large areas. Though I endeavored to write very conservatively I mentioned areas of eight, ten and twelve acres, as having been rendered barren by the accumulation of this salt, nitre, which term was used to designate any nitrate, calcic, magnesic, sodic or potassic nitrate, the essential point being the presence of nitric acid.

Again I endeavored to show that any transportation, leaching and subsequent concentration was inadequate to account for the occurrences of these salts, because they occur on high mesas where there is no wash or transportation from higher lands as well as in low lands. In writing of the presence of nitrates in the waters issuing from the shales, I recognized the fact that it might suggest these shales as the source of the nitrates and endeavored to show that such a conclusion would be unwarranted, for the shales in question contain only 0.03 percent of nitrates and the presence of this small amount was probably due to the water from the higher lying mesas where nitrates occur rather abundantly, which fact is stated in Bulletin 155, p. 42, as follows: "The mesas above these shales are cultivated and bad nitre spots occur on top of them, in one case 80 feet above the level at which the water was taken." Further, that nitre spots occur in different geological formations where these shales do not occur, in alluvial deposits and under our ordinary prairie conditions; in other words, the shales, considered as a source of nitre, would not be available for the explanation of the greater part of the occurrences and we are compelled, on account of their insufficiency, to seek for a more generally occurring source or a cause sufficient to account for all the occurrences, assuming that they have a common cause, which is reasonable, at least, until we are sure that they have different causes in different places.

The relation of seepage to these occurrences of nitre was also discussed and the statement was made that the nitre is associated with a rather uniform and abundant supply of moisture but that in really wet soils it does not appear; on the other hand, at least one instance of its occurrence in well drained land was specifically mentioned and described, as follows: "A small piece of land, a sandy loam, near and some 12 or 15 feet above the river has a dark brown color and has not been productive for several years. This land has received good cultivation, the application of much barnyard manure and excessive irrigation in the hope that the "black alkali" would be washed out." In describing Orchard No. 4, I stated that this land is quite high and slopes to the west and south. Again I mention its occurring on hillsides, which was done to convey to the mind of the reader that the locations in which we meet these occurrences are so varied that it would be doing violence to the facts to attribute it to seepage. I mentioned the muddy condition of the soil in three cases which I discussed and gave the height of the water table, if it could properly be called such, as five and one-half or six feet, a perfectly safe depth for all ordinary vegetation. This question was investigated at various seasons of the year without results, materially contributing toward a solution of the problem. The very first question suggesting itself in connection with the troubles described in Bulletin 155, and one which every intelligent ranchman investigates, is the question of water and if the solution of the difficulties were to be found in an excess of water in the soil the ranchmen themselves would long since have found it out, but even in cases in which I have thought it possible or even probable that the soil water might be too abundant, I have been informed by persons of very different character that the water plane varied from 12 to 16 or more feet throughout a whole section of country. These people had dug cisterns and wells and made other excavations, and their information on this subject is fairly reliable. I am convinced that the muddy condition of the three soils described is rather a result of the presence of the nitre than a cause of the trouble.

Bulletin 160 is more than a popular restatement of the facts of Bulletin 155, in that it gives our observations upon the orchards from September of 1909 till May of 1910, which gave us no reason for modifying any view expressed in Bulletin 155, except to intimate rather strongly, that the seriousness of the problem was even greater than had been suggested in Bulletin 155.

In describing the condition of the land I again state more strongly than before: "This condition then is not restricted to low lands; is not dependent upon the variety of the soil unless it be within very wide limits, and is not due to bad drainage though it is often observed in low, moist places." In order to convey a

definite measure of its effects it was stated: "I know of one orchard from which 110 trees have been removed this—the spring of 1910—another from which 200, and still another from which more than 200 trees have been removed or are dead."

I gave what appeared to me a justifying reason for considering orchard trees rather than some other crop. My reason was essentially this, that the effect, in the case of the apple tree in particular, is so wide-spread and disastrous that no one conversant with the facts can doubt the existence of a very serious evil, and inasmuch as our orchards both old and young received almost constant attention and care, I wanted to appeal to both the knowledge and interests of the people, as I realized that I was setting forth rather startling facts, and if the people did not believe in the existence of the evil any explanation of the cause would be nothing more than an appeal to their imaginations. That I was justified in this course is fully shown by the doubts entertained by persons who are not ranchmen and orchardists but men of education, experience and mature judgment, some of whom when asked for an opinion have reserved their judgment on the ground that they had never seen such conditions as were described.

It was not my intention in either of the bulletins previously issued on this subject to venture upon the question pertaining to the possible influence of the excessive formation of nitre in the soil upon any of the general crops but it seemed wise to make some tentative statements regarding this feature of the question and the beet crop was mentioned as one which had, possibly, already shown the effects of a continuous and, in the aggregate, excessive supply of this salt. Of course, such a bold suggestion would meet with doubt if not with less kindly treatment. I purposely held close to demonstrable facts, i. e., the presence of unprecedented quantities of nitrates, sometimes confined to small areas but often extending so as to involve eight, ten, twenty or even forty acres, or the death of many apple trees scattered over a large territory, all attacked and dying in a similar manner, or the increasing nonproductiveness of the land till total barrenness ensued. I suggested as a cause for the accumulation of these nitrates the action of certain groups of bacteria only after I had considered every other source which might prove sufficient to explain all of the facts. While the facts adduced as the basis of this claim may be open to some objections, I believe that we shall be able to show that it is a fact that the nitrates are formed in situ, but I shall leave the explanation of this fact and the questions, whence comes the energy; are the azotobacter species alone responsible for the fixation and nitrification or do other groups of bacteria play a more important part than the azotobacter in converting the nitrogen into nitric acid, for others to solve.

The task which I set myself is to show that the nitrate *is*

formed in situ, but this is only a part of the purpose of the present bulletin. It is intended to extend the discussion of the occurrences of these nitre spots and to describe further the effects of this nitre on the soil and plants. In a subsequent bulletin I intend to take up, in some degree of fullness, its effect upon the growth and quality of the sugar beet, more especially upon its composition.

Case No. 5—The orchards and localities described in Bulletin 155 will not be treated of in this bulletin except as further observations made since Bulletin 155 was published may seem to justify, when they will be referred to by the number under which they were described in that bulletin. We will continue the numbers beginning with orchard or case No. 5. I visited this orchard, quite a large one, on the 12th of June, 1909. I did not obtain the age of the trees but they were probably not less than 15 years old. They had been sprayed heavily, especially in 1903, 1904 and 1905. There were a few trees in the orchard with corroded crowns, very probably due to arsenic, but arsenic had nothing to do with the trouble that we went to investigate. The condition of the orchard was, in the main, good; we, however, found twelve large trees in a group, with brown leaves and the trees appeared to be dead. The rest of the orchard was in good condition, the foliage was of full size and healthy in color. We learned from the owner that these trees had appeared perfectly healthy until within a fortnight or less. The orchard had not been irrigated as I inferred from the appearance of the surface of the ground in parts of the orchard, but this was due to the overflow of a waste ditch some weeks previous to this time. The soil about these trees was mealy on the surface and felt soft under the foot. We dug a hole near to one of these dead trees, five and a half feet deep. The soil was moist but there was no free water at this depth. I took a sample of soil from a place near to one of the very badly affected trees to a depth of one foot. The water-soluble in this sample amounted to 0.57 percent. It was rich in nitric acid but owing to the small amount of residue at our disposal no analysis of it was attempted.

It was evident that these trees were not drowned by the rising of ground water nor killed by an excessive amount of ordinary alkali. I next visited this orchard on September 21, 1909. More trees were affected and there was no improvement in the condition of any trees previously observed. On November 3 I again visited it and dug a hole five and a half feet deep near a tree which was dying. The soil was wet but there was no free water, and this was at the season when the fall irrigation of adjoining lands was being applied. A sample of soil was taken from the surface of this ground to a depth of two inches. The surface was slightly incrusted and mealy underneath but there was no efflorescence. In places the surface appeared wet, evidently due to the presence of

deliquescent salts. The sample of surface soil taken on this date contained 5.91 percent soluble in water.

ANALYSIS*	I
	Water-Soluble Laboratory No. 873 Nov. 23, 1909
	Percent
Calcic sulfate	20.360
Magnesic sulfate	6.655
Magnesic chlorid	0.459
Potassic chlorid	1.292
Sodic chlorid	45.229
Sodic nitrate	25.843
Iron and Aluminic oxid	Trace
Manganic oxid	0.032
Silicic acid	0.130
	100.000

This analysis shows the presence of five tons of nitrates, calculated as sodic nitrate in the top two inches of soil or a trifle over thirty tons calculated on an acre-foot.

I again visited this orchard for the purpose of further investigating the question of the water table on December 3. It has been stated that on June 12 we dug a hole five and a half feet deep near a tree which had recently died. On this date, December 3, we dug another hole at the same place six and a half feet deep. The ground was quite wet at this depth but there was no free water. It has already been stated that the soil is a sandy loam, and it was sandier at this depth. Another hole was dug seven and a

*In this bulletin all of the analyses have been calculated to one hundred. This has been done because we believe that the reader will be able to compare the results more easily, as they are all reduced to a common basis, i. e., parts per hundred of the dry residue—also to save space. Many of the samples presented difficulties, mostly owing to the presence of very deliquescent and easily decomposed salts such as the chlorids and nitrates of calcium and magnesium—and in a few cases of large quantities of organic matter.

The nitric acid determination in a few samples is undoubtedly too low because of the presence of magnesic nitrate and the continued drying necessary to obtain a manageable residue. Some of these samples intumesced badly and emitted an acid odor, during which some loss of nitric and hydrochloric acids probably took place. The nitric acid was determined in duplicate in every case as NO, and the NO absorbed by means of a recently boiled $FeCl_2$ solution. I believe that the results as presented in the analyses represent the composition of the water-soluble portion of the soils in a water-free condition with a very fair degree of accuracy. It is not, however, intended to assert that the nitric acid is all combined with one base, as appears in the greater number of the analyses, as for instance as sodic nitrate. This is simply a convenient manner of combining it and may in some cases be correct, but in many of these residues it is probably not correct.

There is almost uniformly a trace of manganese in these aqueous extracts, but it has been disregarded for the most part as it seldom exceeds two or three hundredths of one percent.

half feet deep at the same place, where we dug to the depth of five and a half feet on November 3. At this depth the ground was very wet, even muddy. We waited a short time to see whether any free water would flow in but it did not. On May 14, 1910, I again visited this orchard. The condition of the orchard was very bad, many trees had been removed and many more were dying. On June 11, 1910, almost exactly a year subsequent to the first observations made on these dying trees, I visited it again. The orchard was ruined; most of the trees were dead; and worse yet, the land, so far as we can now see, is as thoroughly ruined as the orchard. A large portion of this orchard—six to eight acres—has been dug up.

The orchard immediately south of this one is in a very bad condition; it is, for the most part, dead. No samples of either the soil or the ground water were taken at this place. The owner, a man of considerable education, is fully convinced that the trouble is not due to excessive water in the soil.

The following samples of surface soil from Orchard No. 5 will convey a better idea of the conditions existing in this soil than any words describing them. In No. 947-a the water-soluble equalled 11.6; in No. 959, 3.4; in No. 995, 12.79, and in No. 1013, 7.20 percent of the air-dried soil.

ANALYSES	II	III	IV	V
	Water-Soluble Laboratory No. 947a May 14, 1910	Water-Soluble Laboratory No. 159 June 11, 1910	Water-Soluble Laboratory No. 995 Aug. 25, 1910	Water-Soluble Laboratory No. 1013 Sept. 13, 1910
	Percent	Percent	Percent	Percent
Calcic sulfate	18.437	20.437	8.219	9.123
Calcic chlorid	14.778	———	17.005	20.415
Magnesic sulfate	———	5.999	———	———
Magnesic chlorid	10.474	———	12.295	10.658
Potassic sulfate	———	1.447	———	———
Potassic chlorid	2.273	———	1.434	1.575
Sodic sulfate	———	15.104	———	———
Sodic chlorid	13.726	35.416	8.747	27.708
Sodic nitrate	39.790	21.303	52.071	30.350
Iron and Aluminic oxids	0.132	0.149	0.090	0.051
Silicic acid	0.210	0.235	0.139	0.111
	100.000	100.000	100.000	100.000

The dates on which the various samples were taken, extending over two years and representing the months of May, June, August, September and November, show that the condition is a persistent one, and while it may vary from month to month there was a very dangerous quantity of nitrates in this soil throughout the whole period.

In 1909 I produced decided injury to four-year-old trees by the addition of five pounds of nitre to the soil, within a radius of

about twenty inches around the trunk of the tree. No one has to my knowledge demonstrated how small an amount of nitrates may do injury to an apple tree if placed within reach of its feeding roots, especially at the period of its most rapid growth. My experiments were made to see whether this amount would produce any effect upon the trees and to observe how this effect expressed itself and not with the idea of determining the tolerance of the apple tree for this particular salt, sodic nitrate.

The trees in this orchard, especially the first ones attacked, twelve or more in number, did not turn yellow, dwindle and gradually succumb, but, though they were in full leaf and appeared vigorous and healthy, the leaves suddenly turned brown and drooped and the trees died outright within ten days or a fortnight. As the trees in this orchard continued to die throughout the season of 1910 it may serve a purpose to calculate the amount of nitrate available to an ordinary-sized tree, fifteen years of age. The roots of such a tree will occupy an area represented by a circle forty feet in diameter, at least; this will give approximately 1,200 square feet of surface. All of the feeding roots in this orchard were found to be within two feet of the surface. The sample of soil was taken to a depth of two inches or one-sixth of a foot and there would be two hundred cubic feet of such dirt to furnish nitrates to the tree. Assuming a cubic foot of this sandy soil to weigh ninety pounds, we have 18,000 pounds of nitre-rich soil, 11.6 percent of which is soluble in water, or 2,088 pounds, four-tenths of which (39.97 percent) or 835 pounds consists of sodic nitrate or its equivalent in other nitrates.

In this calculation I have assumed that the soil below a depth of two inches furnished no nitrates—which is altogether contrary to the facts. It may, however, serve to convey a clear idea of the large amount of nitrates present within the feeding areas of these trees, 832 pounds in this case, ready to be moved downward and supplied to the feeding roots, all of which are within two feet of the surface, by a rain or irrigation or any other agent, possibly even by cultivation of the soil. This was in May when the trees were feeding actively. Our sample taken in August is still worse, 12.8 percent soluble in water, placing 2,304 pounds of salts above the roots of the tree with 1,178 pounds of sodic nitrate or its equivalent. When we incorporated five pounds of sodic nitrate with the soil about a four-year-old tree and watered it, we injured some of the branches; when we incorporated twenty-five pounds and irrigated it we killed the tree in four days. It is not probable that every tree in this orchard had either 1,178 or even 832 pounds of sodic nitrate at its disposal but all of the trees in this area, some eight acres or more, died and were dug up between May 1909 and March 1911. Another way to convey an idea of the large quantities of nitrates

with which we are dealing is to express it in tons per acre-foot as was done in Bulletin 155 or in the surface two inches of soil. The figures obtained for the August sample gave us 22.1 tons in the top two inches of soil for each acre of land or practically 133 tons per acre-foot which corresponds to 6.66 percent of the weight of the air-dried soil. These trees had lived and grown healthily, some of them I would say vigorously, for fourteen or fifteen years, till May, 1909, when twelve or more of them died within a fortnight without previously having shown any distress and within the next eighteen months eight acres or more of this orchard died.

Case No. 6—My first observations on this orchard were made in 1908. Some trees scattered throughout the orchard had already died and been removed. While I was satisfied that arsenic had caused the death of some of them, it evidently had had nothing to do with the death of others. At first I had considered seepage to be the possible cause of the trouble. The water plane, however, was stated to be from seven to ten feet below the surface. Subsequent investigation indicated that this statement was correct, besides my knowledge of this section of the country would lead me to expect the water plane to be not less than six feet below the surface. I do not believe that the water plane rises and falls through any great distance, at least I have found no indications of such a fact. The owner stated that the ground turned brown and then things died. The aspect of the land is to the south with a slight depression running northeast and southwest through the orchard. There are some differences of level in different parts of the orchard. I have no notes in regard to the amount of these differences but they are not great, possibly a maximum of twelve feet. A cellar is located near the middle of the east side of the orchard and it is five feet deep with a hole dug about the middle of it. This hole had some water in it in the spring of 1909. More trees, eighteen of them, died during the latter part of the season of 1908 and these were removed in the spring of 1909 after which the orchard was plowed and this portion of it sowed to wheat. The wheat was a total failure as almost none of it came up. The owner attributed this to his failure to irrigate the land. My opinion is that it was not his fault. By July 1, 1909, the orchard was very badly burned and by October a portion of it was dead and leafless. Photographs of this orchard were used as illustrations in Bulletin 155, Plates III and IV, page 26. As Plate III shows the healthy condition of that portion of the orchard which formed the background of Plate IV, which gives an excellent idea of how the orchard had suffered, they are reproduced in this connection as Plate I. This represents the destruction wrought in a single season. These trees, 110 of them, were removed in the spring of 1910, and on July 14, the date of my next visit, the

affected area had been extended very noticeably and many more trees were dying.

A set of soil samples was taken from this orchard May 14, 1909, representing the surface soil, also the first, second and third foot. In taking these samples we dug a hole about four and one-half feet deep. No water was met with but we filled up the hole as soon as we had procured the samples and did not wait to see whether any water would run in or not. These samples were extracted with water and gave as follows, the surface soil 4.68, the first foot 1.86, and second foot 2.09 and the third foot 1.509 percent soluble in water.

ANALYSES	VI Water-Soluble Laboratory No. 784 Surface Soil May, 1909	VII Water-Soluble Laboratory No. 785 First Foot of Soil	VIII Water-Soluble Laboratory No. 736 Second Foot May, 1909	IX Water-Soluble Laboratory No. 787 Third Foot May, 1909
	Percent	Percent	Percent	Percent
Calcic sulfate	29.607	69.830	57.250	37.344
Calcic carbonate	9.679			
Calcic chlorid	6.686			
Magnesic sulfate		5.071	13.249	15.311
Magnesic chlorid	9.729	3.203	3.442	0.670
Potassic chlorid	3.549	1.736	1.265	1.229
Sodic chlorid	32.834	18.780	22.601	41.448
Sodic nitrate	7.239	0.709	1.591	3.402
Iron and Aluminic oxid	0.145			
Manganic oxid	0.234			0.282
Silicic acid	0.298	0.671	0.602	0.314
	100.000	100.000	100.000	100.000

ANALYSES	X Soil Laboratory No. 785 First Foot	XI Soil Laboratory No. 786 Second Foot	XII Soil Laboratory No. 787 Third Foot
	Percent	Percent	Percent
Insoluble	64.820	66.674	68.027
Silicic acid, soluble	5.650	2.927	2.131
Sulfuric acid	0.810	1.282	0.503
Chlorin	0.890	0.333	0.308
Phosphoric acid	0.180	0.242	0.267
Carbonic acid	7.040	7.370	6.636
Lime	7.180	7.730	6.590
Magnesia	2.190	2.967	2.961
Sodic oxid	0.840	0.402	0.494
Potassic oxid	0.690	0.595	0.661
Ferric oxid	3.110	2.890	3.170
Aluminic oxid	2.250	1.354	2.030
Manganic oxid (br)		0.210	0.220
Moisture at 100°	1.470	1.260	1.498
Ignition	2.970	(3.838)	(4.573)
Sum	100.090	100.074	100.069
O equiv. to chlorin	0.200	0.074	0.069
Total	99.890	100.000	100.000
Humus	0.248		
Humus ash	0.194		
Total nitrogen	0.072	0.056	0.055

There is nothing in the results obtained by the ordinary agricultural analyses of this soil to indicate anything unusual unless it be the small amount of total nitrogen present. The method followed in these analyses was the conventional one, digestion with hydric chlorid sp. g. 1.115, etc., and the nitrogen determined by the Kjeldahl method modified for the determination of nitric acid. No. 785 is the first foot of soil from which the surface portion was scraped off in order to obtain the soil without incrustation of effloresced salts, and we have, as shown by the aqueous extract of this sample, a remarkably small amount of nitrates while the second and third foot show decidedly increased quantities. The third foot contains only a little less than the top two inches but is relatively only one-sixth as rich. We have for the top two inches 2,257 pounds, for the next foot 528 pounds, for the second foot 1,332 pounds and for the third foot 2,053 pounds per acre. I do not believe that the nitre in the third foot of soil participates largely in doing injury to the trees unless it be brought nearer to the surface, say within two feet of the surface, by capillarity or some other agent, so that we cannot take this third foot into our reckoning except as a possible source of nitrates. The top twenty-six inches of this soil, however, contained at the time the samples were taken, in May, a little better than two tons of sodic nitrate, a comparatively moderate quantity, provided that these salts were not concentrated within the feeding zone of the roots. But, even as the case stands, there is, assuming 80 trees to the acre, fifty pounds of sodic nitrate to the tree, taking the soil to the depth of twenty-six inches and supposing that the succeeding foot with twenty-five pounds more for each tree does not in any way enter into the problem. I do not know how the amount of nitrates varied during the ensuing season, but, if they increased in this soil as they were observed to do in some others, the aggregate amount present during the season must have been at least twice as great as that given but, be this as it may, 110 trees occupying a continuous area about the point where these samples were taken died within the next four months in the same manner as that in which the trees we poisoned with sodic nitrate and as thousands of others, in lands richer in nitrates, died. The question of the amount of nitrates necessary to kill apple trees would be an interesting one to answer but it is not the object of this bulletin. There are also other questions involved, for instance, to determine the maximum quantity of nitrates available to trees in such lands at any one time, for, it is evident, that if a fatal quantity were available for only a few days, perhaps one day, it might suffice to kill them. We killed a tree in four days. Again it would be interesting to know whether a tree, say 15 years of age, would tolerate more saltpetre in September than in April, May or June,

owing to its different vegetative activity. But none of these questions fall within the scope of this bulletin.

Fortunately we can, in part, answer a question suggested above in regard to whether the nitrates have increased, as we have a sample of the surface soil taken very nearly from the same point at which the surface sample was taken May 9, 1909. The second sample was taken May 3, 1911.

This land is, at this writing, planted to winter wheat. The plants are largely confined to the bottoms of the creases or irrigating furrows. The crests of the creases or spaces between the furrows are mostly bare. The owner thinks that this may possibly be due to the lack of a sufficient amount of moisture to germinate the seed. I do not think that this was the case, as the irrigating furrows are rather close together and as he gave it a fair irrigation, it is not probable that there was so great a lack of moisture as to cause a general failure of germination between the furrows. I think it much more probable that the water flowing in the furrows removed the nitrates far enough from the seed to permit their germination and the establishment of the young plant.

The condition of these plants at this time, May 3, 1911, was very interesting; the plants were large and vigorous, and had an intensely green color, but so many of them were burning that the tips, already browned back on the leaf for three or four, or even more inches, presented a marked contrast to the otherwise luxuriant looking wheat, and it is a question whether even these thoroughly well established plants will endure it to mature their grain.

ANALYSIS	XIII Water-Soluble Laboratory No. 1069 May 3, 1911
	Percent
Calcic sulfate	14.155
Calcic chlorid	20.275
Magnesic chlorid	12.885
Potassic chlorid	1.360
Sodic chlorid	38.496
Sodic nitrate	12.621
Iron and Alumina	Trace
	100.000

Sample 784 was taken in May of 1909. Sample No. 1069 was taken in May, 1911. The ground from which No. 1069 was gathered, in 1911, was occupied by healthy trees in 1908 and the early part of 1909, but these trees died in 1909 and were removed in the spring of 1910. Stated otherwise, this land prior to the summer of 1909 had never contained enough nitrates to injure the trees which had been growing in it for fifteen or more years, but the accumulation of the nitrates in 1909 passed the limits of

tolerance for the apple trees and they died. By May 3, 1911, this land, which showed no nitrate at this place in 1909, was brown and mealy and wheat was not able to grow healthily in it and on a great deal of the ground not at all. A surface sample, taken in May, 1909, from a part of this orchard where the trees had died, gave 4.68 percent soluble in water which contained nitric acid corresponding to 7.239 percent of sodic nitrate. A similar sample, taken in May, 1911, from ground which did not show this trouble in 1909, gave 6.80 percent soluble in water containing nitric acid equal to 12.621 percent of sodic nitrate. As these samples represent the surface portion, approximately to a depth of two inches, we will compare them; in 1909 the surface two inches of a portion of this land where the trees had died contained 2,258.8 pounds of sodic nitrate per acre, whereas a portion of the same land which did not contain enough nitrates in May, 1909 to kill the trees contained in May, 1911, 3,433 pounds, a gain of 1,174 pounds per acre in the surface two inches in two years on the supposition that this soil was really as rich in 1909 as the ground in which the trees had already died, which is not true, so the gain actually exceeds 1,174 pounds of nitrate in two years. Evaporation of ground waters from the surface of this soil is wholly inadequate to account for such an accumulation as this. I will give figures and statements showing that it is very liberal to assume the presence of 0.3 p. p. m. of nitric nitrogen in the ground water and I will support this with further figures in subsequent paragraphs. But 0.3 p. p. m. of nitric nitrogen is equivalent to 1.8 p. p. m. of sodic nitrate equal to 4.896 pounds per acre foot. On the assumption that this nitrate has been brought to this land by the ground waters and deposited by its evaporation we would have to evaporate 239.8 acre-feet in two years or 119.9 acre-feet per annum—whereas our actual evaporation from a free water surface is forty-one inches or it would take 70 years to effect the evaporation from a free water surface required by our supposition in two years from a soil surface. There is another feature of which we cannot lose sight; our ground waters are rich in other dissolved salts and these must be accounted for in some way. Our ground waters seldom carry less than 100 grains per imperial gallon or 1,429 p. p. m. or 3,858 pounds per acre-foot of water according to which we would have to account for 925,920 pounds or 463 tons of alkalis on every acre of this ground which, assuming the alkalis to be as dense as the soil itself, would cover the soil one-quarter foot deep every two years which is evidently contrary to the facts. Our soils are rich in soluble salts, that is salts soluble in water, but they are not covered nor even mixed with any such quantities as this supposition shows must be present. This particular soil is quite rich but we found in the surface soil, two inches deep, in 1909, 4.68 percent and

in the first foot 1.86, in the second 2.09 and in the third 1.509 percent—which the analyses show to be very largely calcic sulfate.

These statements, as well as the following considerations, apply to every individual case considered in this bulletin. The ground waters are wholly inadequate to transport the nitrate, for we have no 120 acre-feet of ground water per annum nor is there any land surface from which to obtain the nitrates. The whole of the irrigated lands in some sections are more or less affected and it is wholly gratuitous to even suggest our native prairies and mountain sides as a source of these nitrates. Our river waters, even those used for irrigation, contain very little nitric nitrogen from 0.00 to 0.4 p. p. m. Our virgin soils show only 8.000 p. p. m. of nitric nitrogen as a maximum—and even this is subject to appropriation by plants and reduction in the soil, so that even though very large areas were to be leached out or washed off this source could scarcely be soberly appealed to as the source of these nitrates.

Case No. 7—This orchard showed the first bad burning about the middle of May, 1909, shortly after the orchard had been heated to protect the crop against frost, about April 27. The trees had continued to grow steadily worse and the owner at first feared that the injury was due either wholly or in part to the gases given off during the combustion of the coal used in heating the orchard. To this question there was a very direct answer, i. e., the water sprouts which had grown since the heating were burning badly.

This orchard presents, in regard to soil conditions, a strong contrast to the last one mentioned, and to all others heretofore mentioned, except Orchard No. 5. The soil is sandy, inclining in some parts of the orchard to a clayey loam. The attack began a little to the east of the center of the orchard. This part of the orchard is not lower than the rest of it. The owner has sprayed very heavily some seasons and is still a heavy sprayer. There were some girdled trees in the orchard but the arsenic had nothing to do with the burning. This burning is quite distinct from a spray burn. We dug a hole near to one of the burned trees five and one-half feet deep. The orchard had been recently irrigated but we found no more than a desirable degree of moisture at this depth. A sample of soil was taken at this time. The depth to which it was taken is not stated in my notes. The water-soluble equaled 0.187 percent. No analysis was made of this material beyond a nitric acid determination which showed an amount corresponding to 5.412 percent of sodic nitrate or 0.01 percent of the air-dried soil, a small amount, still it equals about 22 pounds to a tree taking the soil to a depth of two feet. The family is supplied with water stored in a cistern which is 10 feet deep. I was informed that they did not strike water in digging it. The age of

this orchard was 18 years. The owner stated that he had observed a Lawver tree about three years previous to this time which turned brown on one side but recovered so that it grew healthily the following year. Some of these burned trees put forth a few new leaves which had a whitish yellow color and soon died. We visited this orchard again on November 3, when we found a number of the trees evidently dead, and again on December 3, 1909, when with the help of the owner we dug out a number of the roots and again sought to ascertain the depth of the water table. We followed the roots from the trunk of the tree as far as possible. In one case this proved to be 21 feet at which point we lost it because it had turned abruptly toward the surface and had been cut off by the plow. The root had become so small at this point and other roots were so numerous that we could not identify it with certainty. We attempted to follow other roots but we found it very difficult to do, owing to the presence of such a number of other roots and the smallness of the extreme ends. The greatest depth attained by those that we followed was two feet below the surface. All of the little roots that we encountered in this attempt seemed to be perfectly healthy even to the minute fibrous roots. Th greatest distance that we followed any root was 23 feet. There were only a very few fibrous roots as deep as 30 inches, almost all of them being within 24 inches of the surface. These roots which we dug out belonged to the trees which had been badly burned. Not only were the roots of the trees apparently healthy but the crowns and larger roots near the trunk were also apparently perfect. The owner suggested that we dig up one of these trees but as the root system seemed to be in such good condition I suggested that it would be better to let it and the rest of them stand till the next spring, 1910, and see whether they would recover or not. The trees were left standing, but they did not recover—they had already been killed.

Wishing to dispel, if possible, all doubts in regard to the part played by the ground water in the death of these trees, we dug another hole near one of the trees just described. The orchard had received a heavy irrigation on September 25, and the next few days following. The ditch, 120 feet east of where we dug this second hole, had stood full of water for three or more weeks in September. It had overflowed and formed a small pond at the edge of the orchard. The soil at the place where we dug this hole was sandy and we encountered the water plane at five and one-half feet, or two and three-quarters feet below the deepest roots that we observed. On May 14, 1910, four days after the orchard had been irrigated, I found the leaves on some trees burning. There seemed to be so good as no recovery from the injury of 1909. On June 11 the condition of this orchard was very bad indeed, and

PLATE I.—See page 10.

evidently growing worse. It was evident that a considerable number of trees would succumb, indeed some were already dead and conditions were not improving in the least. The water table was not within five feet of the surface in an adjoining orchard though recently irrigated. The affected area had extended so as to embrace nearly the whole of this old orchard. There is a young orchard on still higher land which is not yet affected. By September 13, 1910, the old part of the orchard was practically ruined. The water table at that time was not within five and a half feet of the surface. In this orchard we have a decidedly sandy soil, inclining to a clayey loam in places, and not an adobe soil which often becomes muddy at comparatively shallow depths as described in Bulletin 155. At no time have we found the water table less than five and a quarter feet below the surface and practically no roots at a greater depth than two and a half feet, and but few below two feet. The surface of this soil is brown and mealy, and is rich in nitrates and the orchard is in very bad condition.

The orchard immediately east of this presents the same conditions of soil with the water plane deeper than five and a half feet below the surface. The top soil is brown and mealy and many of the trees are dead, some having died in 1909 and others in 1910.

The orchard immediately to the south is worse than either of these as the trees are practically all gone.

This orchard, No. 7, has been given in such detail because it is the first old orchard planted on this type of soil with the water table well below the surface, to which we have made so many visits, and in which we have been able to watch the progress of the trouble. Orchard No. 5 went rather more rapidly, as did also No. 6. The soil of Orchard No. 5 is likewise a sandy loam and the water table is likewise low, but the land itself is possibly a little less favorably located than that of Orchard No. 7.

I will give but two analyses of soil from Orchard No. 7, or rather I will give analyses of the water-soluble portions of surface samples, one taken from near a young tree, seven or eight years old, which was burned but slightly at the close of the season, September 13, 1910, No. 1014; the other No. 1071, taken in May, 1911. The water-soluble of No. 1014 equalled 2.974, and of No. 1071 equalled 6.276 percent.

ANALYSES	XIV Water-Soluble Laboratory No. 1014 Percent	XV Water-Soluble Laboratory No. 1071 Percent
Calcic sulfate	23.270	25.022
Calcic chlorid	17.550	24.160
Magnesic chlorid	15.930	17.420
Potassic chlorid	4.044	4.023
Sodic chlorid	35.432	24.268
Sodic nitrate	1.420	4.686
Iron and Aluminic oxid	2.069	0.162
Silicic acid	0.285	0.258
	100.000	100.000

This orchard was beginning to burn in the early part of June, 1911, earlier than in preceding years.

Case No. 8—This is a young orchard set in 1908. The history of the ground as given to me is as follows: Prior to 1904 the whole piece of land was productive; in this year a brown patch appeared and the land became unproductive. It was covered thickly with manure in 1904 and again in 1906. The conditions were not improved. In 1908 it was set to orchard and planted to beets. The trees did not do at all well in this area and some of them died. The beets came up very poorly; they were replanted twice and the stand was still very poor, the beets produced being over-grown and having large tops. My information is that the quality was poor. In my field notes mention is made of the fact that the land outside of this area appears as heavily charged with alkali as the area itself, but the owner asserted that this land was very productive and subsequent observations lead me to believe that the statement is correct. This land was irrigated ten or twelve times during the season, each time excessively in the hope that the "black alkali" might thereby be removed—to use the owner's language: "I washed it till the soil was white." I took a set of samples from this land in April, 1909. The soil is sandy loam with a more sandy subsoil. I dug to a depth of five feet, without further change in the soil and without striking the water table. This place is practically on the river bank where the soil section is sand lying on top of coarse gravel. The river bed is now from twelve to fifteen feet below the level of this land and the brown mealy soil occurs within fifty feet of the edge of the bank. It is scarcely possible to obtain better drainage conditions than these. This is, in fact, the reason for my making particular mention of this place. At first I thought that this condition was in general largely due to an excess of moisture, such an excess as to be of itself injurious to vegetation, but I do not find such to be the case. Orchards No. 5 and No. 7 are also on sandy loam soils and not adobe soils which retain water persistently. They are, however,

not drained so well as this land, lying as it does on the river bank, the most remote part of it being scarcely more than three hundred feet from the river, and twelve or fifteen feet above its bed. The trees that had died in 1908 were replaced in the spring of 1909. On May 6, I have noted that the brown area appears in good condition but that the trees are not doing well. November 2, same year, I visited this place again and noted that the apple trees in this bad spot had died. The ground had been recently disced and seemed in good condition, but those spots which had escaped being stirred were brown and mealy. Some one attempted to conduct a truck garden immediately north of and contiguous to this ground, beginning in 1907. At this time, November, 1909, it was almost black in color, encrusted a little and mealy underneath.

In July, 1910, the condition of the land was worse than I had ever seen it, not only the trees but also corn and peas showing the effects of the nitre.

One sample of soil was sent to me in February, 1908, presumably taken to a depth of from eight to twelve inches according to directions. This sample yielded 1.262 percent of salts soluble in water, containing nitric acid equivalent to 11.230 percent of the soluble salts or 0.142 percent of the air-dried soil, or 5,680 pounds, nearly three tons per acre-foot. Other samples of soil were collected at this place at subsequent times, April 21, 1908, April 6, 1909 and November 2, 1909.

Further back from the river we have seepage beyond a question. We found the water table at from two to eleven feet, but the water at the latter depth was under considerable hydrostatic pressure and rose in the holes dug to within two and a half feet of the surface. The party who procured some of the water samples for me described this fact as follows: "It kept getting wetter until I struck gravel, at four feet, when the water rushed in and bubbled up as if under pressure. The water rose sixteen inches in thirty minutes, and finally stood at two and one half feet below the surface." The gravel here referred to is very probably the natural drainage into the river and this water passes beneath the land which we have just described.

These general conditions are given only because they contribute to a better understanding of the question. I have been repeatedly asked whether the seepage water does not bring these nitrates into these localities. This question has been raised by the character of the samples of drain and ground waters whose analyses are given in Bulletin 155, p. 27 *et seq.* I stated in connection with them that the presence of nitrates in the seepage water issuing from the shales, for instance, was easily accounted for by the cultivation of the higher lying mesas, on which these nitre spots occur and in some cases are even prevalent. If the seepage water from any

section were wholly derived from such a source there would be nitre introduced into the seeped lands with the water unless the nitrates were reduced or otherwise removed. This, however, is not the case. The seepage in almost every case is made up of the leakage from irrigating canals and ditches or from excessive irrigation. The lands before being brought under irrigation do not contain nitrates or even nitrogen in quantities worthy of note, in fact the supply of this element is quite limited. The waters used for irrigation are taken from our rivers and lesser streams which are supplied by the snows which fall in our mountain sections. While there may be a few exceptions to this statement, it is in the main correct, and no exception of any weight, so far as I can recall, applies in any measure to any of the lands treated of in Bulletin 155 or which will be considered in this.

I know of no lands anywhere which would be more likely to be affected in such a manner than land immediately north and a little east of this particular tract, and concerning the seeped or water-logged condition of which no question can fairly be entertained. As already stated we encountered water as close as two and a half feet of the surface, which fact alone does not prove that the ground is necessarily unproductive; but this ground was nearly barren. It had been in alfalfa, a little of which was still living at the time of which I am writing. The soil was wet and heavily charged with the ordinary alkali of the section. Three samples of this ground water were taken in November and December of 1907. The alkali in this immediate section is higher in chlorin than is usual. This is one of the places referred to in Bulletin 155 as especially rich, so rich in chlorin that the salt, sodic chlorid, present may possibly be injurious to vegetation. Inasmuch as this question has been suggested and as I know of no place more unfavorable to my views regarding the subject, I will give analyses of soils, of samples of alkali and of the three samples of ground waters from this section. They are not from the same spot but were taken from places near one another, within one quarter of a mile and not more than one half mile from Orchard No. 8. The alkali and the soil were taken from land that had at one time been cultivated. The rows were still visible and the manure in the rows had not yet rotted. The ground was at this time bare but not brown and greasy in appearance. I do not know whether any thing could have been made to grow on it or not. No attempt to do so has been made at any time during the past three years. The surface portion of this soil was extremely rich in alkali. I observed, at the time these samples were taken, in some depressions in this field, crystals of sodic sulfate from one and a half to two and a half inches long. The soil sample, taken to a depth of one foot, yielded 2.45 percent soluble in water. The second and third

foot were taken as one sample and gave 4.27 percent soluble in water.

ANALYSES	XVI Water-Soluble Labratory No. 632 First Foot	XVII Water-Soluble Labratory No. 633 Second and Third Foot
	Percent	Percent
Calcic sulfate	41.882	42.122
Magnesic sulfate	8.747	18.397
Sodic sulfate	10.847	5.747
Sodic chlorid	34.014	28.019
Sodic silicate	1.276	1.479
Manganic oxid		0.070
Ignition	3.234	4.184
	100.000	100.000

These water-soluble portions were tested for nitric acid and there was not enough present to give a reaction with ferrous sulfate and sulfuric acid. That the water-soluble should be made up so largely of calcic sulfate is what one would expect, because this salt, as the mineral gypsum, can be seen forming veinlets and small aggregations throughout the mass of the soil. This is the case to a greater extent in the second and third than in the first foot. The quantity of sodic chlorid is larger than usual but is still within the limits of tolerance for almost all plants.

ANALYSES	XVIII Soil Laboratory No. 632 First Foot	XIX Soil Laboratory No. 633 Second and Third Foot
	Percent	Percent
Sand	48.951	47.747
Silicic acid (sol.)	22.377	17.945
Sulfuric acid	0.708	3.194
Chlorin	0.387	0.599
Phosphoric acid	0.156	0.217
Carbonic acid	3.968	3.709
Lime	4.624	5.877
Magnesia	2.650	2.864
Sodic oxid	0.740	1.033
Potassic oxid	1.082	1.356
Ferric oxid	4.344	3.374
Aluminic oxid	5.286	7.405
Manganic oxid	0.168	0.675
Water expelled at 100°	1.707	2.933
Ignition	2.986	(1.207)
Sum	100.134	100.135
Oxygen equiv. to chlorin	0.087	0.135
Total	100.047	100.000

Another soil in which the conditions were worse even than in the preceding is represented by the next sample. This ground

had been an alfalfa field and a few of the plants were not yet entirely dead. The crowns and roots showed that it had recently been a good stand and that the plants had been large. The water table was in this case within two and a half feet of the surface.

ANALYSIS	XX Soil Laboratory No. 625
	Percent
Sand	66.822
Silicic acid (sol.)	11.303
Sulfuric acid	0.042
Chlorin	0.703
Phosphoric acid	0.042
Carbonic acid	4.458
Lime	4.294
Magnesia	2.339
Sodic oxid	0.653
Potassic oxid	0.660
Ferric oxid	3.089
Aluminic oxid	2.005
Manganic oxid	0.051
Water at 100°	1.250
Ignition	2.192
Sum	100.663
Oxygen equiv. chlorin	0.159
Total	100.504

ANALYSIS	XXI Alkali Laboratory No. 622
	Percent
Calcic sulfate	6.893
Magnesic sulfate	17.373
Sodic sulfate	27.868
Sodic chlorid	43.466
Sodic silicate	0.316
Ignition, etc.	(4.384)
	100.000

The following three samples are ground waters taken within the area under consideration, all of them taken in November and December of 1907.

ANALYSES	XXII Ground Water Laboratory No. 647	XXIII Ground Water Laboratory No. 668	XXIV Ground Water Laboratory No. 669
Total solids in grains per Imp. Gal.	883.54	1052.29	1076.81
	Percent	Percent	Percent
Calcic sulfate	19.726	14.318	10.976
Magnesic sulfate	22.618	24.687	30.105
Magnesic carbonate	———	———	1.827
Potassic sulfate	0.700	0.967	———
Potassic carbonate	———	———	0.715
Potassic chlorid	———	———	0.308
Sodic sulfate	5.744	11.060	———
Sodic carbonate	2.431	3.872	———
Sodic chlorid	44.670	40.405	49.732
Sodic silicate	0.869	0.841	0.149
Manganic oxid (br)	0.097	———	0.059
Ignition	(3.143)	(3.850)	(6.129)
	100.000	100.000	100.000

There is not enough nitric acid in this alkali or in any of these soil extracts or water residues to give, when as much as one-half to one gram of the dry residue is taken, a satisfactory test with ferrous sulfate and sulfuric acid, and some of them give no reaction with diphenylamine and sulfuric acid.

There is not another instance of the occurrence of nitre within this state which is so favorably located for justifying the theory of concentration from adjoining lands as this one and it is for this reason that I have set forth these facts pertaining to the composition of the alkali, the soils to a depth of three feet, the aqueous extracts made from these soils, and the solids held in solution by the ground waters. The results of the analyses show that even if the soil of Orchard No. 8 had been saturated with the ground waters which had drained through this area it would not, at this time, have become impregnated with nitrates but with sulfates and chlorids. These ground waters, however, do not saturate the nitre soil and it is a question whether they ever rise or in any other manner find their way into it and consequently cannot possibly account for the nitrates for two reasons; first, there was so good as no nitrates in either the soil lying to the north of this orchard or in the alkali which, in places, was abundant on its surface, or in the ground waters, which came near to the surface in parts of the area; second, because these ground waters do no find their way into this orchard soil which is underlaid by gravel and is well drained.

A great deal has been said and somewhat written about alkali and seepage. I will remark in passing that while seepage and alkali usually accompany one another they constitute two distinct subjects. We have many examples of lands rich in alkali which are not now wet enough to be objectionable, and I shall in a subsequent bulletin give specific data which are the basis for the

statement that both water and alkali may be quite abundant and the land still be productive. These are very undesirable conditions but they alone are not so fatal as some people would have us think. In all events they constitute problems distinctly different from the nitre problem, and are not so closely related to it as even I at first thought. My original description of these occurrences of nitre showed that I considered it as dependent upon a constant, optimum supply of moisture. This condition is met with near the outer edges of wet places. The nitrates do not appear where there is a great excess of water. On the other hand they are not confined to places which are seeped, of which fact the orchard in question, No. 8, is a good example, as is also Orchard No. 7. In fact, Orchards 1 and 2, Bulletin 155, are the only cases given in which an excessively wet condition of the soil was observed but no proper water table was found in these at a depth of six to six and a half feet. Such, then, are the conditions surrounding this orchard No. 8, and the little garden tract immediately north of it. I have already stated that the soil is sandy and the section at the river bank, which practically forms the southern boundary of the field, shows a section of twelve to fifteen feet, the upper six or seven feet of which is sand while the lower portion is a coarse river gravel. A sample of surface soil, taken two inches deep in April, 1909, gave 4.42 percent of the air-dried soil as soluble in water. Sample No. 875 contained 10.86 percent of salts soluble in water.

ANALYSES	XXV Water-Soluble Laboratory No. 772 April, 1909	XXVI Water Soluble Laboratory No. 875 Nov, 1909
	Percent	Percent
Calcic sulfate	35.266	24.810
Magnesic sulfate	3.197	3.238
Magnesic chlorid	14.673	15.235
Potassic chlorid	2.109	1.911
Sodic chlorid	33.841	50.704
Sodic nitrate	10.508	3.944
Iron and Aluminic oxid	———	0.158
Sodic silicate	0.406	———
	100.000	100.000

We have in No. 772 the nitrates equivalent to 0.464 percent of the top two inches of the soil, equal to 3,096 pounds or one and one-half tons of nitrates per acre taken to a depth of two inches or at the rate of nine tons per acre-foot. In No. 875 we find the sodic nitrate equal to 0.424 percent of the surface soil, giving us practically the same amount of nitrates per acre as No. 772.

ANALYSES	XXVII Water-Soluble Laboratory No. 877 Surface Soil	XXVIII Water-Soluble Laboratory No. 778 Sample taken 8 inches deep top 2 inches, removed April, 1909
	Percent	Percent
Calcic sulfate	15.345	38.643
Calcic chlorid	3.521	———
Magnesic chlorid	14.611	———
Magnesic sulfate	———	11.082
Potassic chlorid	2.215	———
Potassic sulfate	———	9.500
Sodic sulfate	———	2.473
Sodic chlorid	51.474	33.854
Sodic nitrate	12.596	3.784
Iron and Aluminic oxid	Trace	0.100
Manganic oxid	0.094	0.042
Silicic acid	0.144	0.522
	100.000	100.000

In this case we find in April, 1909, that the top two inches of this soil showed the presence of one and a half tons of sodic nitrate. Another sample taken in November of the same year, and perhaps one hundred and fifty feet north of where the sample was taken in April, gives us essentially the same amount, one and a half tons in the top two inches. But the same depth of soil taken November 2, the same year and very nearly at the same point where the April sample had been taken, showed the presence of almost four tons, 3.978 tons, of nitrate in the top two inches per acre. A sample of this soil taken from the third to the tenth inch inclusive in April, 1909, or eight inches of the soil, after the top two inches had been removed, showed the presence of 2,306 pounds, a little over one ton to the acre taken to this depth, eight inches. This land had been excessively irrigated ten or twelve times during the season of 1908 with the idea of washing out the alkali. There were no signs of trouble in this land prior to 1904 according to the statement of its former owner.

Sample No. 875 was taken from ground which had been used as a truck garden in 1908. I scarcely need to state that the truck garden was a failure. This young orchard, Case No. 8, is used for the same purpose, i. e., gardening, and with excellent results except in this brown area. Analyses XV to XXVII inclusive are analyses of the alkali, the soil, and the ground waters which lie to the north and east of this land, not quite surrounding it but including the land through which the ground waters would have to move in order to reach this orchard. These samples were taken in 1907 and contained no nitrates—or only such traces as may be found by extracting any soil. I may state, though it is very evident, that neither Bulletin 155 nor this one deals at all with such quan-

tities of nitric acid or nitrates as are usually understood when nitrates in the soil are spoken of, but of the occurrence of such unusual quantities as to be fatal or injurious to vegetation. I shall endeavor to deal with the general condition, of which only extreme cases are presented in this bulletin, in a subsequent one.

The analyses of the adjacent, almost circumjacent soils, the alkalis and the ground waters have been given to show that they have nothing to do with the conditions in this orchard soil, and especially nothing to do with the nitrates. Apropos to the influence of the drainage and the character of the soil upon this question, we have chosen one sample of dark brown surface soil from this orchard collected within fifty feet of the edge of the river bank, and a second one, also a dark brown surface soil from another piece of land of which no other mention is made. Both of these pieces of land are naturally well drained but in addition to this there are four tile drains in the second piece which contains only thirteen acres. One of these drains was carrying about two inches of water while the other two that I saw were not running at all. There is still another drain on the land adjoining this on the east, which was carrying a large flow of water. The owner of the land stated that all of the drains carry water after he irrigates the land, showing conclusively that the land drains freely. The soil is sandy, very similar to that of Case 8, with which we have joined it. I was informed that some of the drains have been laid four years. Laboratory No. 1067 is a sample from Case 8, collected March 27, 1911, fifty feet from the river bank. We give two analyses of this sample, one of the water-soluble portion, the other a mechanical analysis of the soil. The water-soluble in this sample equaled 8.165 percent of the air-dried soil. Laboratory No. 1076 is a similar sample collected from the drained land and also within fifty feet of the river bank and not less than twelve feet above the river bed. These soils are so similar that the mechanical analysis of the one faithfully represents the other. The water-soluble in No. 1076 equalled 9.882 percent of the air-dried sample.

ANALYSES	XXIX Water-Soluble Laboratory No. 1067 March 27, 1911	XXX Water-Soluble Laboratory No. 1076 May 2, 1911
	Percent	Percent
Calcic sulfate	21.826	19.494
Calcic chlorid	23.971	1.647
Magnesic chlorid	20.534	16.435
Potassic chlorid	2.880	1.716
Sodic chlorid	26.846	57.106
Sodic nitrate	3.807	3.374
Iron and Aluminic oxid	———	0.101
Silicic acid	0.136	0.127
	100.000	100.000

ANALYSES	XXXI Mechanical Analysis Laboratory No. 1067 Percent
Above 1.0 mm. dia.	0.708
1.0 mm.-0.5 mm. ..	1.222
0.5 mm.-0.25 mm. ..	9.851
0.25 mm.-0.05 mm. ..	47.582
0.05 mm.-0.01 mm. ..	21.021
0.01 mm.-Clay	8.419
Clay, by diff.	11.197
	100.000

XXXII Drain Water Labratory No. 1201 Percent	
Calcic sulfate	21.380
Magnesic sulfate	25.249
Potassic sulfate	0.695
Sodic sulfate	5.119
Sodic chlorid	42.874
Sodic carbonate	4.683
	100.000

	p. p. m.
Total solids	8489.00000
Ammonia	0.01800
Nitrogen as nitrites...	0.00003
Nitrogen as nitrates...	0.10000

The two pieces of land discussed at this time differ only in this, that one of them has been drained for four years and the other is not artificially drained at all. We observe that the soil consists of 47 percent of fine and very fine sand, further that there is 21 percent of silt and a fair amount of clay. The samples 1067 and 1076 are alike in location so that they are perfectly comparable in every respect except that the land represented by No. 1076 has been drained for four years; some of the drains having been put in recently, others of them at earlier dates. The samples are both surface samples, that from the undrained land contains 8.165 and the drained land 9.882 percent of water-soluble salts which in both cases consist of sulfates, chlorids and nitrates. The amounts of nitrates contained in the samples give us for No. 1067, 2,072 pounds calculated for the top two inches, while No. 1076 gives us 2,223 pounds calculated for a like depth, or calculated for the acre-foot of soil, we have 12,432 and 13,336 pounds respectively.

The drain water was collected from an east and west drain crossing the northern end, while the sample of soil, No. 1076, was collected from the southeastern corner of this land. It may be further stated that there are two other east and west drains between the drain from which the water sample was taken and the point where we took the soil sample and in addition to this there is a north and south drain running within a few feet east of this latter point which is itself not more than fifty feet north of the river bank.

I may also add that the soil on top of and along the side of this north and south drain is in the same condition as the sample actually taken.

The object in stating these details is evident, i. e., to show that these conditions are independent of the seepage question and

that drainage is not of itself and necessarily a cure, and still further to show that these nitrates are not deposited by the evaporation of ground water coming from other lands. The owner explained to me that the depth of the drains vary—which is evident without statement—but he added that the gravel below the soil is very irregular in its surface so that the depth of gravel penetrated by the drains is quite different. We will not consider any greater depth of soil than is represented by our samples, i. e., two inches, but we will calculate how much of this drain water would be required to furnish the nitrate which we actually find in these two inches of soil, and we will take this as 2,150 pounds. The samples of soil and drain water were taken in May, 1911. The drain water contains 0.1 part per million of nitric nitrogen equivalent to 0.6 part per million sodic nitrate; taking an acre-foot of water at 2.7 million pounds it gives us 1.62 pounds of nitrates per acre-foot of water and we would have to evaporate 1,327 acre-feet of this drain water to obtain this 2,150 pounds of nitrates which we find present at this time. The evaporation of this amount of water would require, assuming that the annual evaporation amounted to sixty inches (at Ft. Collins it is only 41 inches) two hundred and sixty-five years. This drain water carries 8,489 parts of total solids per million which, calculated on the 1,327 acre-feet of water necessary to yield the 2,150 pounds of nitrates, would yield 30,414,840 pounds of salts, a quantity sufficient to cover the land more than seven feet deep, if we suppose them to have the same density as the soil itself.

The changes in the conditions of these soils have taken place within the past few, say six, years, and these conclusions to which we are forced if we suppose that these nitrates have their origin in the evaporation of the ground waters are evidently false. We know that no 1,327 acre-feet of water have evaporated to dryness on this land in this time and it is evident that our country is not covered nearly eight feet deep with calcic chlorid and other salts and we are likewise quite as sure that land which up to six years ago, and this assumed period is from three to six times as long as the facts indicate, has not been two hundred and sixty-five years in going to the bad.

I have described the condition of the land north and east of north of this orchard, designated No. 8, and from one-fourth to one-half mile distant, as having the natural color of ordinary adobe soil, in 1907 and 1908, with an abundance of ordinary white alkali in its surface portions, and stated that sulfate of soda crystals up to two and a half inches long occurred in the lower portions of this land, especially in depressions in the surface soil. In the spring of 1911 practically the whole surface in this land is dark brown in color and greasy in appearance. I dug a hole four

and a half feet deep in a low spot in the field, and while the ground was wet, there was no free water. It is very probable that the water table in this land varies exceedingly from place to place, indeed it is very probable that one might choose a place and dig a hole twelve or more feet deep and find no portion of it wetter than the top six inches, possibly not as wet, and at another point encounter water within three feet or less of the surface; further, these points may be close together in the field. A sample of surface soil with its alkali was taken at the point where I dug the hole four and a half feet deep; this was mixed with samples of like soil from other parts of the field. This sample is so rich in nitrates that the aqueous extract from two grams of it gives a strong reaction for nitric acid. In 1907 the extract of the soil gave none. There are many square miles of such lands. The following analysis is to be compared with analyses of Laboratory Nos. 622 and 632. This land was already seeped in 1907, almost if not quite as badly then as now. The water-soluble in sample No. 1070 equalled 18.176 percent.

ANALYSIS XXXIII

	Water-Soluble Laboratory No. 1070 Surface Soil May 2, 1911
	Percent
Calcic sulfate	21.104
Magnesic sulfate	15.766
Potassic sulfate	2.391
Sodic sulfate	1.676
Sodic chlorid	58.263
Sodic nitrate	0.518
Iron and Aluminic oxid	0.052
Silicic acid	0.230
	100.000

The percentage of sodic nitrate in this analysis is not large compared with some of our samples, but compared with the quantities present in 1907 it is quite as striking as the changes in the appearance of the land itself which was then the uniform gray of our adobe soils, now it looks as though it had been irregularly moistened with a heavy crude oil and though the large quantities of salts present are not favorable to an abundant development of nitrates we now find nitrates present at the rate of one and nine-tenths tons per acre-foot where, four years before, we found none.

Case No. 9—I visited this orchard for the first time May 18, 1910. The age of the trees still living was twenty-eight years. No disease had appeared in the orchard till the season of 1909. During this season about two and one-half acres of the orchard, two hundred trees, showed serious trouble and died in about six weeks. These trees had been removed from the orchard at this time, May 18, 1910, and used to stop the washing away of the

river bank. The trees were not only old, they were also large, some of them measuring fifteen inches in diameter, and the owner stated that he had gathered from them crops of fifty boxes to the tree. The soil is a light sandy loam with a decidedly sandy subsoil, underlaid by gravel at a depth of from six to eight feet. We dug a hole five feet deep eight days after irrigation and found the ground only fairly moist. The drainage of this land is so free that when the northern part of it is irrigated freely a well in the southern part will show a rise of water within a few hours, less than twenty-four, and falls quickly.

After the dead trees were removed the land was prepared for planting to some crop. It appeared to be in the most excellent condition. Corn was subsquently planted but the stand obtained was very poor indeed. The owner attributed this to the quality of the seed which he said appeared to be good but it did not come up. I dug up samples of the seed corn which were thoroughly preserved, the grains were full, plump, fine-looking ones and there was an abundance of moisture to permit germination. This soil was brown and mealy on the surface. A sample was taken at this place where the corn had failed to come up and an analysis of it will be given later. This land continued to become more and more mealy and the remaining portion of the orchard became involved to a greater extent as the season passed, till, by the middle of September, at least one-half of the total area, five acres or more, was decidedly brown, and a further number of these old apple trees were affected. The corn crop was a complete failure. The sample taken, 989, represented the surface soil of a considerable area and was made by taking portions at various places, mixing as thoroughly as possible and then cutting it down to a manageable size; the depth of the soil represented is four and a half inches. The water-soluble equalled in No. 989, 2.884; in No. 892, 2.398; in No. 1074, 3.909, and in No. 989a, 6.96 percent of the air-dried soil.

ANALYSES	XXXIV Water-Soluble Laboratory No. 982 July 19, 1910	XXXV Water-Soluble Laboratory No. 989 July 11, 1910	XXXVI Water-Soluble Laboratory No. 989a Sept. 12, 1910	XXXVII Water-Soluble Laboratory No. 1074 May 7, 1911
	Percent	Percent	Percent	Percent
Calcic sulfate	30.263	24.664	8.756	37.982
Calcic chlorid	5.888	9.298	14.117	
Magnesic sulfate				1.726
Magnesic chlorid	14.930	15.217	9.217	10.817
Potassic chlorid	3.190	2.861	1.632	3.898
Sodic chlorid	41.757	43.832	60.219	35.135
Sodic nitrate	3.605	3.033	5.906	9.889
Iron and Aluminic oxids	0.152	0.138	0.084	0.087
Silicic acid	0.215	0.232	0.069	0.466
Carbon		0.725		
	100.000	100.000	100.000	100.000

The soil designated as Laboratory No. 989a, was very brown on its surface, and when exposed to the atmosphere, after drying at 100°, absorbed enough moisture to cause it to adhere so tenaciously that one could press it into clumps in the hand which retained the form of the fingers. The aqueous extract had a brownish yellow color which became decidedly brown on evaporation. This color continued to go into solution even after the chlorids and sulfates had been completely washed out. The color could scarcely have been due to humus in the presence of such quantities of lime salts, besides the soil is poor in humus and the strong brown color on the surface of this soil is not due to this cause. It would have been difficult to have obtained a sample of this soil entirely free from the azotobacter pigments in which to determine the humus. Prof. Sackett has obtained cultures showing that the azotobacter pigments are soluble in water. This accounts for the deportment of this sample.

The mechanical analysis given for Laboratory No. 1067 is quite as applicable to the sample No. 989 as to the one of which it was made and likewise the agricultural chemical analysis is quite as applicable to 1067. The localities are probably as much as two miles apart but the soils are similar in location and character.

ANALYSIS	XXXVIII
	Soil, top four inches Laboratory No. 989
	Percent
Sand	59.993
Silicic acid (sol.)	15.000
Sulfuric acid	0.430
Carbonic acid	3.450
Chlorin	1.561
Phosphoric acid	0.220
Lime	4.890
Magnesia	1.783
Potash	0.794
Soda	1.557
Ferric oxid	3.542
Aluminic oxid	2.189
Manganic oxid	0.370
Water at 100° C.	0.500
Ignition	(4.072)
Sum	100.351
O. equivalent to chlorin	0.351
Total	100.000
Total nitrogen	0.118

The ordinary agricultural analysis of this sample indicates that it is an excellent soil, which inference would be further justified by the mechanical analysis of No. 1067. While these inferences are fully justified by the analytical results and even further by the fact that all that was said of the preceding case,

Case No. 8, in regard to the drainage or water conditions, the simple fact remains that the twenty-eight-year-old apple trees, beginning in 1909, have practically all died, and the corn planted in 1910 was a total failure as a crop. When we consider samples 982, 989 and 989a, we see that the surface five inches of the soil contains from 1,440 to 1,660 pounds of sodic or other nitrate per acre. Approximately this depth was taken because these samples were taken after the corn had failed to come up and it was thought that the results obtained would give us an idea of the lower limits of nitrates which would prohibit germination. We knew perfectly well that this would not establish anything beyond giving us an idea of what quantity will prohibit the germination of corn. The quantity which effects this is less than 0.09 percent of the soil. Sample No. 1074 is a surface sample from the place where oats, potatoes, etc., will not grow but pear trees continue to do quite well. We find that the top two inches of this land carries 2,578 pounds of nitrates per acre—I surmise that the pear trees endure this apparently better than apple trees and the other plants because they feed at greater depths and it may be true, as it actually seemed to be, that they are more tolerant of these salts than the other plants, but they are not immune for I have seen pear trees that have been killed just as the apple trees were killed. I repeat that the facts adduced pertaining to the two pieces of land mentioned under Case No. 8 apply with full force to Case No. 9, in fact these cases might have been discussed as a single one if the distance between them and the age of the orchard in Case 9 had not made it ill advised to do so.

Case No. 10—This is a peach orchard and the part referred to in this paragraph has been reset a number of times, the last time to pear trees, but without success. The part very badly affected is about one-third of an acre in extent, but there is probably three acres in all that is damaged by these conditions. This soil is a sandy loam three feet deep, underlaid by a coarse granitic gravel. The surface is brown and there is no vegetation. The land is no lower than the surrounding country. There was no excessive water in this or in adjacent lands. Two samples of soil were taken, one to a depth of one foot, No. 874; this sample showed the presence of 1.127 percent soluble in water; the other, No. 880, was a surface sample taken to a depth of one and one-half inches which showed the presence of 5.528 percent of the air-dried sample soluble in water.

ANALYSES	XXXIX Water-Soluble Laboratory No. 880 Nov. 2, 1909 Percent	XL Water-Soluble Laboratory No. 874 Nov. 2, 1909 Percent
Calcic sulfate	30.513	52.204
Calcic chlorid	2.412	
Magnesic sulfate		6.991
Magnesic chlorid	13.990	10.594
Magnesic nitrate	5.210	
Potassic chlorid		5.199
Potassic nitrate	6.809	
Sodic chlorid		1.276
Sodic nitrate	40.841	22.981
Iron and Aluminic oxid	0.092	0.393
Manganic oxid	Trace	Trace
Silicic acid	0.133	
Loss		0.362
	100.000	100.000

This is perhaps the most surprising occurrence of this difficulty that I have to record. This land is most favorably located, but it is not the only piece of land affected in this manner in this section. The owner told me that he had removed an old orchard principally because the varieties were poor, and that he had not been able to get the young trees to live. In the case of No. 880 we have been compelled to unite a part of the nitric acid with magnesium and potassium and we have 52.86 percent of the total soluble salts composed of nitrates, giving us the top inch and a half, the depth to which the sample was taken, 14,610 pounds to the acre—7.3 tons, or 116,880 pounds of nitrates to the acre-foot of such soil—58.4 tons.

Sample No. 874 represents the next succeeding foot with 5.7 tons per acre-foot. We actually have in the top thirteen and one-half inches of this land 13 tons of nitrates, principally nitrate of soda. This land is wholly barren. There is a cellar at the edge of this piece of land, six feet deep, the bottom of which is in the coarse gravel previously mentioned. In March, 1911, the bottom of this cellar was not only dry but actually dusty when stirred.

Most of the pear trees set in the spring of 1910 died before mid-summer and but few survived till the spring of 1911. The pear tree seems to be very tolerant of these salts, especially so when once established.

Case No. 11—This orchard is located near a ditch. The trees were attacked in July or August and died outright. The land had been heavily manured and when I visited it, it had just been irrigated and was, of course, wet on the surface. We dug a hole five and a half feet deep and found no signs of any excess of water. The soil is a sandy loam. I took two samples, one of

them one and a half inches deep; this gave 1.45 percent soluble in water and showed very little nitric acid. The other sample was taken to a greater depth, eight inches, and showed the presence of 1.762 percent water-soluble and a very decided quantity of nitric acid.

ANALYSES	XLI Water-Soluble Laboratory No. 876	XLII Water-Soluble Laboratory No. 877a
	Percent	Percent
Calcic sulfate	80.305	43.457
Magnesic sulfate	8.591	19.658
Potassic sulfate	2.998	10.206
Potassic chlorid	4.458	
Sodic sulfate		1.030
Sodic chlorid	2.302	13.494
Sodic nitrate		11.373
Iron and Aluminic oxid	0.193	0.147
Silicic acid	1.103	0.635
	100.000	100.000

It is seldom that we have so great a difference in the character of the soluble salts in samples of soil from the same place. This is probably due to the heavy irrigation that this land had just received. It had apparently moved the whole of the nitric acid down into the soil to a greater depth than one and a half inches and most of the sodic and potassic salts with it. In this respect these two analyses are quite interesting. The eight-inch sample shows the presence of 5,344 pounds per acre in this section of soil, or a little over four tons to the acre-foot.

Case No. 12—This is one of the worst cases that I have observed. The soil is sandy and the orchard is contiguous to Orchard No. 11 and west of it. In June, 1910, I observed the beginning of a very general burning in the orchard and a few trees, perhaps twelve to twenty, were already dead or in a bad condition. I spoke to the owner in regard to the matter but he thought that it was a case of spray burning and attributed the trouble to a faultily prepared lead arsenate. He was very positive in regard to the matter. I saw this orchard in September when it was in a very bad condition, probably upwards of six acres being involved and very many of the trees will not survive the season. The conditions of this orchard are the same as in Orchard No. 11, and there is no question of drainage or alkali. Both orchards are fairly old ones, the oldest trees being probably not less than sixteen years and the youngest twelve to fourteen years old. When the owner of Orchard No. 12 became convinced that something more serious than spray burning had happened to his trees he manured the land and irrigated heavily. The development of this orchard

in 1911 would have been interesting to watch, if the owner had not removed the six-or-eight-acre block of trees.

Cases Nos. 13 and 14 — These orchards have suffered greatly, especially No. 14, during the past seasons; fifty acres or more in the two orchards have been seriously affected, and many trees have died. The soil conditions vary considerably in different portions of these properties; some of the land, a small portion, is low, but the most of it is well located. I have joined these properties because they are close together but not adjoining and because they present, in the main, essentially the same problems. They are both pretty well protected against seepage, being nearly if not the highest ground under irrigation in that section. One of them has a very deep wash on the north and west sides of it and a system of drains running through the lower land. The questions pertaining to Orchard No. 13 may be more involved than any which I have heretofore described, but this is not the case with No. 14. I gave the analyses of two samples of drain water from Orchard No. 13 in Bulletin 155. They were as follows:

ANALYSES	XLIII Residue from Drain Water Laboratory No. 610	XLIV Residue from Drain Water Laboratory No. 792
	Percent	Percent
Calcic sulfate	23.202	22.352
Magnesic sulfate	36.662	31.586
Potassic sulfate	0.705	1.502
Sodic sulfate	29.991	24.775
Sodic chlorid	2.863	9.050
Sodic carbonate	4.093	4.120
Sodic nitrate	2.275	6.500
Silicic acid	0.209	0.115
	100.000	100.000

The solids in these waters are essentially sulfates. The small amount of carbonates indicates the amount of this salt to be expected in the soil. We find in the drain waters from soils more favorably conditioned than this one, from seven to twenty-three percent of the total solids held in solution consisting of this salt, carbonate. I unfortunately do not know the amount of water discharged by the respective drains at the time the samples were taken but the total solids varied only slightly. No. 610 contained 637.3 grains of total solids per imperial gallon; No. 792, 622.65 grains. A drain water flowing from a piece of strongly alkalized ground contained 113.8 grains, sample taken in April. Another sample from the same ground, taken in July, contained 72.8 grains, and another in February three years later contained 160.5 grains. Another drain water flowing from a somewhat alkalized area, but

by no means a very bad one, contained 62.2 grains per imperial gallon.

The nitric nitrogen was determined in two of these samples, one containing 0.24 part, the other 0.48 part per million, whereas No. 610 carried 34.5 parts and No. 792 carried 96.37 parts nitric nitrogen per million, or No. 610 carried 143.8 times as much as the first drain water and No. 792 carried 200 times as much as the second drain water. While the percentage of sodic carbonate in the residue obtained from these waters varies greatly, the actual amount of sodic carbonate per million of water is nearly the same, for instance, 323, 355, and 364 parts per million, which serves to show how very high the nitrates in these two waters are in comparison with the amounts present in drain waters from ordinary alkali land.

The flow from these drains undoubtedly varies with the irrigating season. I do not know whether the drains are stopped up or not but they discharged no water for several months during the spring of 1911.

The land included in Orchard No. 13, as stated before, presents involved conditions. A portion of it was seeped and badly so, ten or twelve years ago, and was drained a little over ten years ago. This land in the meantime has been benefited to such an extent that good crops of wheat, forty-five bushels per acre, have been harvested from it. There are portions of this area through which the drain passes and which one would think should receive the full benefit of the drainage which, though not wetter than other portions, are unproductive. I took samples from such places several years ago. In taking these samples I recognized three conditions, a thin crust on the surface, of which 8.317 percent was soluble in water; a portion immediately underneath this crust, of which 7.680 percent was soluble, and the soil proper, the first foot of which after the two preceding portions had been removed, gave me 1.330 percent soluble in water.

ANALYSES	XLV Water-Soluble Laboratory No. 819 Crust on surface	XLVI Water-Soluble Laboratory No. 818 Portion under the crust	XLVII Water-Soluble Laboratory No. 816 Soil one foot deep
	Percent	Percent	Percent
Calcic sulfate	13.926	51.858	19.863
Magnesic sulfate	20.841	11.043	14.511
Potassic sulfate	2.027	2.084	2.611
Sodic sulfate	44.021	16.734	52.334
Sodic carbonate		0.872	
Sodic chlorid	16.427	16.793	8.795
Sodic nitrate	2.525	2.435	1.646
Iron and Aluminic oxid	0.067	0.032	0.098
Silicic acid	0.166	0.149	0.142
	100.000	100.000	100.000

A very large portion of this orchard, at least thirty-five acres, has been removed. Some of the trees may have been killed by an excess of water. I am fully prepared to accept this as an adequate and very probable cause in some cases and yet the question presents itself why they should have lived to be fourteen or sixteen years old and die several, eight or ten, years after the drains were put in and the water had been removed. I realize that it is exceedingly difficult to present all of the facts and the questions which arise in this connection so that persons who have never seen these conditions can apprehend them. But though the facts may be perplexing and it may be difficult to give a satisfactory reason why seepage should kill these trees, I am still thoroughly convinced that excessive water injured some of them. This, however, does not apply to the greater part of this orchard. Almost, but not quite, the highest portion of this orchard with the deep wash, previously referred to, bounding the section on two sides, has suffered severely, in fact, several acres of it, ten or more, have been entirely destroyed. The trees have not been killed by winter injury, nor by arsenic, so far as I have been able to detect and I have tried to determine this point, but a great many of them have been burned and have died just as in the other orchards described. In the summer of 1909 and again in 1910 I watched the progress of the destruction of this orchard, marking trees in May and June to see them dead in August and September.

Samples of the surface soil from the higher sandy portion of the orchard, where the destruction of the trees has been complete, gave the following results: the water-soluble equalled in 815, 0.985, in 1061, 1.467, and in 1075, 8.590 percent of the air-dried sample.

ANALYSES	XLVIII Water-Soluble Laboratory No. 815 June 3, 1909	XLIX Water-Soluble Laboratory No. 1061 March 28, 1911	L Water-Soluble Laboratory No. 1075 May 2, 1911
	Percent	Percent	Percent
Calcic sulfate	17.521	59.460	28.162
Magnesic sulfate	27.166	15.714	9.470
Magnesic chlorid	———	———	9.141
Potassic sulfate	3.768	3.466	———
Potassic chlorid	———	3.264	3.932
Sodic sulfate	11.925	———	———
Sodic chlorid	18.683	4.540	5.086
Sodic nitrate	20.367	13.057	44.035
Iron and Aluminic oxid	0.065	———	Trace
Silicic acid	0.505	0.499	0.174
	100.000	100.000	100.000

Sample No. 1075 is the surface, mealy portion formed in the irrigating furrows after the last irrigation. This land has been sown to oats this year, 1911, but they are not in good condition.

The water-soluble in this sample equalled 8.590 percent and the nitrates equaled 44.0 percent of this, or 3.78 percent of the sample as it was gathered, showing that the surface soil is now very rich in nitrates. Sample No. 1061 is an actual sample of this soil taken to a depth of from four to six inches; the sample is a composite one from ten different points in the field. We see that it contains practically 1.5 percent of the water-soluble salts of which 13.0 percent was sodic nitrate which gives us 3,900 pounds of nitrates in the top six inches of the soil. This land lies on and above the wash alluded to which is eleven feet ten inches deep and is actually encroaching upon this land on both the north and west sides, which ought to secure excellent drainage especially as the land is not a heavy adobe soil, still it will puddle and retain water more persistently than one would think. The presence of the nitric acid in the first sample of soil, No. 815, taken at the base of one of these trees was a surprise to me, though I knew of its occurrence in adjoining portions of the land where the trees had already died. This whole section of trees, probably ten acres, has been dug up.

It is useless to attempt to present to oneself any questions in regard to what would have been the condition of this orchard and land had it not been drained, as it was a little over ten years ago. I am satisfied that the drainage system carries off the excessive water whether it is from the irrigation applied or from other sources and establishes a zone and certain areas where there is a comparatively uniform and moderate, but still an abundant supply of moisture which renders possible the development of the nitrates, if other conditions are favorable. What the optimum degree of moisture may be I do not know but my observation leads me to believe that a constant supply amounting, near the surface, to 18 or 20 percent, is sufficient for a rapid development of the trouble. After this is thoroughly established it seems to modify the moisture conditions of the soil as has been indicated by direct assertion of this fact and further by describing the ground as a veritable mud.

Orchard No. 14 is also a large orchard, but has quite a different soil. The burning has been very general and serious, at least twenty acres being involved, some of it on rather high and sloping land, some of it on lower and level land. The developments in this orchard during the season of 1910 were sufficient to cause the manager and the owners the gravest anxiety, while the developments in the past month, May, 1911, are extremely serious.

In this case we probably have an illustration of the effect of the irrigating water washing the nitrates down into the feeding area of the roots, and thus causing the damage, for some of the soil, while it is stained brown, is not at all in a bad condition. The former manager of this property kept the orchard well cultivated and the soil was in fine condition throughout the season of

1910, so that there was no good opportunity to observe the formation of crusts and mealy portions. The irrigating furrows, however, showed the brown lines very strongly in places. A sample of the soil taken from the northeastern section of the orchard to a depth of one foot showed only 0.062 percent of the matter soluble in water, but this soluble portion reacted like a pure nitrate solution. The trees were burning in this section of the orchard at the time the sample was taken. I had known for several years that a small part, possibly one-quarter of an acre, of this orchard, close to a deep wash, was affected with this trouble, but in the early part of June, 1910, I found the trouble more general and it grew quite rapidly in severity and extent till there was scarcely a tree in a large portion of the orchard but that showed more or less burning, and the present outlook is very bad.

ANALYSES	LI	LII
	Water-Soluble Laboratory No. 1063 March 28, 1811	Water-Soluble Laboratory No. 1072 May 2, 1911
	Percent	Percent
Calcic sulfate	10.388	31.808
Calcic chlorid	36.807	12.813
Magnesic chlorid	5.312	14.940
Magnesic nitrate	9.946	
Potassic chlorid		2.329
Potassic nitrate	1.727	
Sodic chlorid		1.983
Sodic nitrate	35.560	35.556
Iron and Aluminic oxid	0.066	0.267
Silicic acid	0.194	0.304
	100.000	100.000

Sample No. 1063 was taken in March and No. 1072 in May, 1911, from the southwestern section of the orchard. The total area of this orchard is ninety acres. A few trees died in this section of the orchard in 1910 but the death rate in May, 1911, is most alarming. Many trees that leafed out fully in the early part of the month, May, 1911, were killed outright by the 30th, as many as six or eight consecutive trees in a row, all succumbing in exactly the same manner. The water plane of the lowest portion of this land was at this time four and three-quarters feet below the surface. I wish to emphasize the following two facts; first, that apple trees in our country do not root deeper than two and a half feet as a rule; second, that it is very improbable that even the oldest reader of this bulletin has ever seen anything in any way comparable to the facts here presented, and I am fully convinced that they are so entirely beyond his observation and knowledge that he can neither conceive of nor justly pass judgment upon them for he does not know the facts.

I have at all times avoided anything approaching a dissertation

upon the facts believing that no statement of them can be more forceful than the facts themselves, but men who may have seen many things and never seen the like of this and others also judge such things to be impossible because they have not seen them and no one has, heretofore, described anything comparable to them. In these facts lies my only justification for the following statement relative to this case. Some five or six years ago I found in the southeast corner of this orchard a few dead trees, killed, as I then believed, by nitre. The ground was mealy and had that softness under the foot which we have learned to be peculiar to the earlier stages of this condition and sometimes persistent throughout the course of its development, even to the utter ruination of the land. No further trouble seemed to develop in this orchard for several years except that this bad area extended slowly from year to year. I visited this orchard but once or twice in 1909, and if there was any general burning of the orchard I neither saw it nor was it called to my attention. That there was some burning is understood, especially in the southeastern section. In 1910, however, the burning was very general throughout the ninety acres. A portion of the orchard was decidedly bad and many trees, the actual number I do not know, died and were removed.

In the northeastern section of the orchard many trees that so far as was known, were in good condition in 1909, were in bad condition and the leaves were burning in July, 1910. Even I had difficulty in pursuading myself that much of the injury was not due to freezing dry. The fact remains, however, that the leaves were burning in just the manner that nitre burns them; further, the sides and crests of the irrigating furrows were streaked with brown, which we have learned to be an almost infallible sign of the presence of nitrates. Holes were dug in this section of the orchard without striking water but the trees were being injured. In the spring of 1911 a party kindly bored a hole at my suggestion to determine the depth of the water plane; he found the soil dry at a depth of six and a half feet. At the time of my last visit to this orchard, May 30, 1911, the trees at this point had not yet begun to burn. The leaves were large and deep green in color. One would infer from the conditions as they presented themselves that too little water had been applied to this section. I have no contour map of this orchard but this northeastern section is patently the highest portion of it and the slope is to the south. A little way down in the orchard we found the leaves of the water sprouts burning to such an extent that there could be no possible question concerning the cause. This season, 1911, is the first time that I have seen burning to any noticeable extent before the middle of June, but this year it is very common at this date, May 30.

In 1910 almost every tree throughout the central portion of

PLATE II.—See page 41.

No. 1 is the upper figure

this orchard showed in August and September more or less burning and here and there a tree wholly succumbed. Many trees, however, were only severely injured, either by having one or more limbs entirely killed or the extremities of the branches killed back varying distances. As yet this section of the orchard does not show the burning badly at all; it is too early and the trees have not had a liberal supply of water.

The western part of this orchard was rather bad, and many trees showed burning last year, but the burning did not take place till the latter part of the season, from mid-summer till autumn. This year, however, many trees that came into full leaf in early May had already been killed by the thirtieth of the month. I visited this orchard on the second and again on the thirtieth of this month and while I have seen other orchards destroyed quickly I have nowhere seen anything surpassing this in the extent of the injury and the rate of its accomplishment. The ground water was four and three-quarters feet below the surface. The surface soil was dry but brown and mealy. The disc had cut about three inches deep and the sides and bottom of the cut looked as though crude oil had been uniformly distributed over them. Sample No. 1063 was gathered from the surface of this ground on March 28, and was taken to a depth of two or more inches. It was a composite sample made up of smaller samples from several places. Sample 1072 was likewise a composite sample taken from the sides and bottom of the cut made by the disc. These samples represent the salts soluble in water and contained in the top two inches of the soil, where the trees are now dying very rapidly, and we see that they agree in showing 6.158 and 6.197 percent of such salts, 47.233 percent of the former and 35.556 percent of the latter being composed of nitrates. Calculating the nitrates present in the top two inches of this soil, we obtain 9.6 tons per acre for the sample taken in March from the surface soil and 7.6 tons for the sample taken in May from the sides and bottom of the disc cuts or furrows, or calculated on the acre-foot, 58 and 44 tons respectively. The ground where the samples were taken is lower than a portion of the orchard but the ground is still so sloping that we cannot explain the presence of this large quantity of nitrates by supposing them to represent the washings from the rest of the orchard.

Plate II shows the condition of some of the trees in this orchard on June 23, 1911. The upper photograph, Fig. 1, represents a tree which at this time showed no effects of the nitrates. The lower one, Fig. 2, represents a tree which developed a full foliage in May and was dead at the time the photograph was taken, June 23, 1911. These two trees do not stand more than fifty or sixty feet from one another. The only reason why trees even

this far apart, were chosen was because we could not get a good view of an unaffected tree standing in the next row and contiguous to the dead tree represented by the lower photograph.

In a preceding paragraph I stated that on May 30, 1911 the trees were burning badly in the southwestern portion of the orchard, as many as six or eight consecutive trees in a row being attacked and dying in the same manner. On June 23 I counted thirty-five consecutive trees in one row which were all attacked to a greater or less extent. Of these thirty-five trees not less than twenty-five were already dead and of the remaining ten five were already so badly injured that there was no hope of their recovery.

Case No. 15—Under this number I shall present two adjacent orchards, without going into any details. I first noticed one of these orchards about four years ago. At that time about one and a half acres of the land was bare; the few trees that were still standing were dead. The surface of the soil was brown. I visited this orchard in 1909 and took a sample of the soil to a depth of one foot. The condition of the land did not appear to be very bad but it had been recently cultivated which operation effectually conceals this condition if carefully done. This sample yielded 3.580 percent of water-soluble which afforded the following results:

ANALYSIS	LIII
	Water-Soluble Laboratory No. 779
	Percent
Calcic sulfate	30.528
Magnesic sulfate	19.901
Potassic sulfate	1.878
Sodic sulfate	23.006
Sodic chlorid	12.951
Sodic nitrate	18.307
Manganic oxid	0.267
Silicic acid	0.162
	100.000

This analysis indicates the presence of a little more than 13 tons of sodic nitrate to the acre-foot.

There is another orchard immediately to the north and east of this to which my attention was directed in the spring of 1911. Drains were laid in this land in the autumn of 1910 with the idea of washing the soil by heavy irrigation and depending upon the drains to carry off the leachings of the soil with the excessive water which might be added or which might possibly accumulate from other sources. The soil is a sandy loam passing into a clayey loam in places. The water plane, determined by means of a series of wells, was four and a half feet below the surface. Some of the

trees at this time, May 1, 1911, were burning quite badly though the leaves were not yet fully developed. It is unusual to observe this burning of the leaves in any degree so early in the season and very much more so to meet with such marked cases of it as these trees presented. Unfortunately I do not know how high the water plane rose during the season of 1910, but information elicited by specific inquiry in regard to this point did not suggest an undue amount of water as the cause of the trouble or as the probable source of the nitrates. I visited this orchard again on May 30, 1911, at which time the destruction of the orchard not only seemed a certainty but was already far advanced. The following analyses represent the surface soil and the water from a well located near by a burning tree. This sample of water was sent by the owner.

ANALYSES	LIV Water-Soluble Laboratory No. 1073 March 28, 1911	LV Water Residue Laboratory No. 1200 May 12, 1911
	Percent	Percent
Calcic sulfate	24.275	36.596
Calcic chlorid	8.658	———
Magnesic sulfate	———	2.194
Magnesic chlorid	8.577	11.654
Potassic chlorid	1.951	2.107
Sodic carbonate	———	5.040
Sodic chlorid	39.187	41.992
Sodic nitrate	17.075	Minute trace
Iron and Aluminic oxid	0.088	0.078
Silicic acid	0.189	———
	100.000	100.000

Sample No. 1073 represents the surface soil, an inch and a half or at most two inches deep, taken beneath a tree which was already burning. This sample yielded 5.768 percent of salts to water, of which a little over 17.00 percent, 17.075, was nitrates, giving us 6,500 pounds, three and a quarter tons, of nitrates in the top two inches of this soil per acre. Sample No. 1200 is the ground water taken from a well near to another burning tree which has since died. This water contained 10,094 p. p. m. of total solids, but contained so little nitric acid that five grams of the residue gave with hydric and ferrous chlorids only a minute trace of nitric oxid. This test, like all of the nitric acid determinations, was done in duplicate. It is a striking fact that this ground water within four and a half feet of the surface on which an abundance of nitrates occur should be so nearly destitute of even a trace of nitric acid, but this is the second case; we have already given one case in which this is so and we have still another which will indicate the same thing. In the case of sample 1201, a drain water, we have given even fuller data, showing the presence of 8,489 parts of salts per million with only 0.018 p. p. m. of ammonia, 0.00003

p. p. m. nitrogen as nitrites and 0.1 p. p. m. of nitrogen as nitrates, which could scarcely be possible if the surface salts were washed down into this ground water to any extent, and contrariwise all of these samples agree in leading us to most extremely improbable conclusions if we consider them to be the source of the nitrates. While this is not yet an extreme case the results are most striking and most evidently false, for if this ground water were the source of the nitrates and it were as rich as this drain water we would have to assert that 40,122 acre-feet of it had been evaporated to dryness on each acre of this orchard which would mean a mass of water 7.5 miles deep. This amount of water would deposit 541,670.6 tons of salt on each acre of which only 3.25 tons, the amount now present in the top two inches of this soil, would be nitrates, and the time required to effect this, assuming the evaporation to take place from a free water surface at the rate of five feet per annum, would be 48,128 years. The facts, on the contrary, are that these apple trees grew healthily for ten years or more until within the last two or three years which is conclusive proof that these nitrates were not present previous to this time, say three years ago, in sufficient quantities to do any damage, but within this time the limit of tolerance has been passed and this orchard has been destroyed.

It is evident from the results in all the cases of ground waters given that it is not water derived from the surface of the land which has passed through the soil and now forms a sheet of water beneath this soil but probably represents, in large measure, the leakage from the irrigating ditches and other similar sources, for we have already given samples of such waters as have without any reasonable doubt come from the soil, i. e., passed through the soil of nitrate areas, and they are rich in nitrates. Further, this ground water, especially the drain water previously given owes its immediate origin to the gravel which underlies the sand, and which, as elsewhere stated, constitutes the natural drainage of this section. I do not know whether the section where the well is located is underlaid by gravel or not, but the water agrees with the others here given in containing so good as no nitrates. Another point is the absence of ammonia and nitrites from this drain water, which can only be interpreted as indicating that no reduction of nitrates can have taken place in the areas from which this water came. The reader is referred to Analysis IX, Colorado Experiment Station Bulletin 155, pp. 12 and 13, for the description and composition of a water derived from a nitre soil. We cannot extend the consideration of this subject at this time.

Case No. 16—Orchard No. 3, described in Bulletin 155, pp. 16-18, has grown worse and many trees, not previously described,

have shown burning to a very serious extent. A little to the east of this place is a piece of ground which some one has tried to bring under cultivation. The piece of land is not very large and lies between two ridges and beside the public road. An open drain was run north and south through the center of it, from the north end of which another open drain was run parallel to an irrigating ditch across the north and northeast end of the east half, to intercept leakage from the ditch. These ditches were not well cared for and their efficiency was greatly reduced owing to the indifference of the owner. A large irrigating canal runs on the east side of the public road and is six or more feet below it, while this piece of land lies on the west side of the road.

The west half of this land was planted to oats last spring, 1910. The condition of the field on September 13, is shown in the upper figures, Plates III and IV. That of Plate IV shows the oats that survived. The photograph conveys a good idea of the size and sharp delimitation of the piece, also of the rank growth made by the plants, they being well above the waist of a medium sized person. The photograph, however, does not convey any idea of the extremely dark green color of the plants. The other figure, Plate III, shows the condition of the rest of the field, the western portion, and the irrigating creases, also that the land was entirely bare, there being only a very few Russian thistles that had survived. These photographs show in a most excellent manner the brown stained margins on the spaces between the creases, even the slight encrusting and puffed up condition which is very characteristic of extreme cases of this trouble, can be recognized in Plate III. These pictures show that the ground immediately back of this, north of it, is higher and some of it is uncultivated, while other portions of it support old and healthy orchards. The pictures also convey a fairly good idea of the length of the field, as the public road runs only a few feet, perhaps thirty, this side of the picture. The length may be four hundred feet. I did not measure it but I think that it cannot be more than this. The north and south ditch runs a little to the east of Plate IV, and the irrigating ditch at least six feet deeper than the lower end of this field runs within forty or fifty feet of its south side. I have already given too many details relative to this piece of ground. The growth of the oats on ground which is neither higher nor lower, neither wetter nor drier than the rest, indicates that it is really not a question of seepage and drainage. This ground was not very wet at any time that I have seen it. It was wet enough to justify the ditching, and the results have been disappointingly small. I interpret this as being in harmony with many other observations, that while this land would be considered as seeped land the chief difficulty is not the water but the bacterial flora of the soil.

A sample of the surface soil was taken from that portion of the field represented in Plate III immediately in front of the person who is actually holding the sample. This sample was taken only to a very shallow depth, scarcely more than one inch; it yielded to water 8.83 percent after being thoroughly well air-dried.

ANALYSIS	LVI Water-Soluble Laboratory No. 1012
	Percent
Calcic sulfate	5.941
Calcic chlorid	26.566
Magnesic chlorid	4.469
Magnesic nitrate	21.527
Potassic nitrate	4.107
Sodic nitrate	37.269
Silicic acid	0.121
	100.000

Case No. 17— The trouble in this orchard came to my notice for the first time in July, 1910. Inquiry elicited no satisfactory information relative to the presence of any burning of the leaves during the preceding year. I, however, became fully convinced of one thing, namely, that while it is very probable that the trouble was present in 1909, even to the extent of killing a few trees, it was not so general as it became during the early part of the season of 1910. The location of this orchard is very favorable; the soil is of the best quality and the drainage is excellent. The red mesa-soil is uniform in appearance and texture for a depth of four and a half feet, when it changes to a gravel as shown by a hole dug by a badly burnt tree. The land had been irrigated probably a week prior to the date on which I dug this hole and took my samples. We found, however, no excess of water in the soil. The irrigating water, if it had at any time made a portion of the soil excessively wet, had already drained out to such an extent that the soil was no more than in good condition, even the foot of soil next to the gravel was not excessively wet, perhaps between twenty and twenty-five percent of its weight being water. This orchard consisted of a younger and an older part. The burning was in most cases very moderate, so moderate that one would be surprised if the result should be fatal unless the soil conditions should grow worse. A few trees had already died from this cause, though there were other dead trees with girdled crowns to which their death was probably attributable. There is no question of seepage involved in this case, but there is a good supply of irrigating water and a small ditch flowing just west of the orchard. The prevalence of this trouble throughout this orchard and the intensity of the burning on a few trees were matters of surprise to me. I had known of the

occurrence of nitrates in very large quantities in this section for two years, but this and some others were new and wholly unexpected occurrences. I took two samples of soil, one to a depth of three inches, No. 977, the other from the fourth to the fifteenth inch inclusive, No. 978. The water-soluble in No. 977 equalled 2.92, in No. 978, 0.54 percent.

ANALYSES	LVII Water-Soluble Laboratory No. 977	LVIII Water-Soluble Laboratory No. 978
	Percent	Percent
Calcic sulfate	40.376	50.910
Magnesic sulfate	22.470	15.972
Potassic sulfate	3.686	8.639
Sodic sulfate	3.606	16.814
Sodic chlorid	23.930	6.039
Sodic nitrate	4.902	Trace
Iron and Aluminic oxid	0.196	0.288
Silicic acid	0.834	1.338
	100.000	100.000

Sample No. 977 gives us 65.5 pounds of nitrates available to each such tree as this, assuming that the roots occupy a circle of ground forty feet in diameter and that the whole of the nitrates in the top three inches, is by any means brought within the feeding area of the roots.

As I have elsewhere stated I do not know how small a quantity of nitrates will suffice to produce a burning of the leaves. The tree in question was burned, but scarcely enough to produce serious injury. Our observations would have to be continued into, if not through, the season of 1911 to form any reliable judgment in regard to this point.

This land is so located that it is difficult to believe that these nitrates could have been washed from any adjoining lands, and if they were brought to the surface by capillary attraction they must have existed in the soil itself, but our analysis of the soil taken from the fourth to the fifteenth inch inclusive shows only a trace of nitrates in the aqueous extract. It is also out of the question to think that the irrigating water, snow water, might contain enough nitrate to permit of such a concentration as we find even in this case. These points are mentioned in this connection because in many cases the conditions legitimately admit the question of transportation from higher lands either by seepage or washing. That is, they could fairly be raised whether they actually apply or not. A case in point, i. e., Case 8, has been presented in considerable detail to enable the reader to judge for himself whether washings from the higher lands or the seepage from them could possibly account for the nitrates occurring in the land described. The presentation of the analyses given is itself a proof that I have most seriously

considered these possibilities, but I have failed to see how these theories of accounting for the presence of nitrates, never before met with in arable soils in such quantities and over such large areas, so far as I know, apply to these cases and especially to Case 8, which, as is stated in the presentation of it, is of all the cases discussed probably the one most favorable for the application of these usual explanations.

This is by no means the only instance of the occurrence of nitrates in this immediate neighborhood but it is the best example of the general effects of the nitrates in ground that we would usually consider almost entirely free from any objection that I can recall. There are very much more severe cases of this trouble in the neighborhood but the land is not so well located for orchard culture. One of the most striking cases in point was a five-or eight-acre orchard planted on ground that sloped toward a slight depression. A deep drain ran at the base of the slope and two lines of underdrain, six feet deep, extended up into the orchard. We dug a hole three and a half feet deep at a point which I thought a favorable one to find water but I found none. At three and a half feet we encountered a stratum of marl and below this there is, as shown by the ditch and drains referred to, a coarse gravel with some marl. The surface of this ground was very brown and mealy. The trees on July 18, 1910, were burning very badly and many of them were already dead. The owner stated that they began to die during the season of 1909, but I did not learn whether the trouble began in the spring or summer.

A number of other instances of trees similarly located could be mentioned. In some section of our orchard districts it is difficult to find an orchard which does not show more or less of the trouble at some time during the season. The trees that are at all seriously affected seem to have no recuperative power.

Case No. 18— This case, like several others, presents more than an orchard, but as an orchard is actually involved I have retained the designation. This is quite fully justified not only because a part of the land is set to apple trees but also because they present a marked case of this trouble. The case is an involved one; in part of the land there is an excess of water, in other portions the soil is shallow, a stratum of marl coming near to the surface, but in other portions the conditions are good, or fairly so. It is exclusively of the better part of the orchard that I shall write. The trees were twelve years old the first time that I saw them, now going on three years ago, and so far as I have been able to learn they had not at that time shown any of this trouble, though I took a sample of soil on my first visit to the orchard in order to test it for nitric acid. This sample contained 2.126 percent

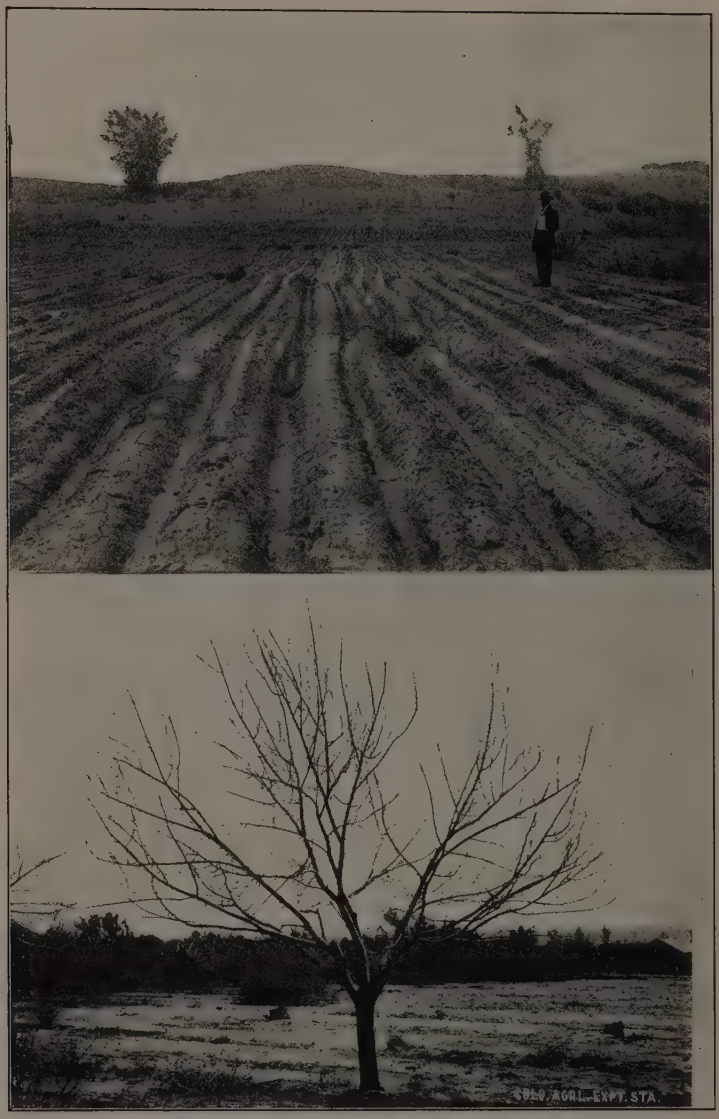

PLATE III.—See pages 45, 62 and 63.

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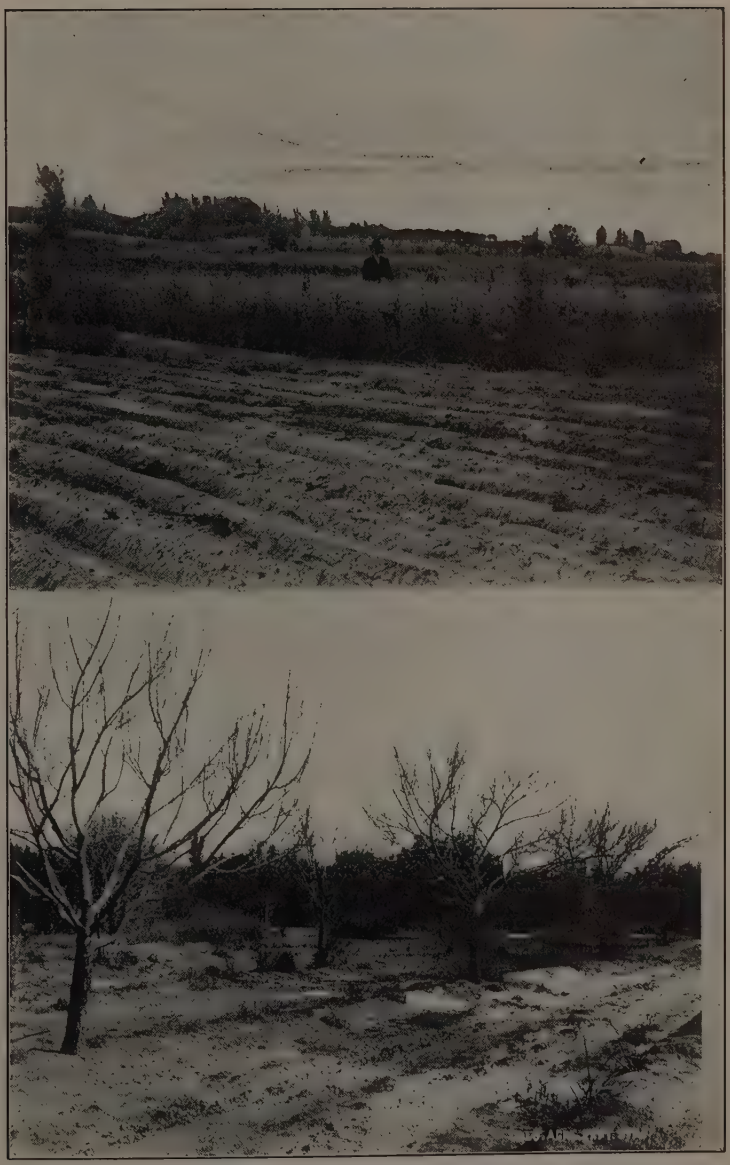

PLATE IV.—See pages 45, 63 and 67.

No. 1 is the upper figure

soluble in water and reacted strongly for nitric acid. The reaction depended on in all cases is that with ferrous sulfate and sulfuric acid. If a few grams of soil, from 10 to 25, will not give with 20 to 30 cc. of water, a solution which will give a decided reaction with these reagents it scarcely belongs to the class of soils, with which we are concerned. The owner put in a short drain to protect a portion of his orchard which he feared might be suffering on account of excessive water. This drain never collected much water, and was entirely dry on my next visit. The trees in this part of the orchard were at this time, July 23, 1910, burning badly.

We had in this orchard an excellent opportunity to compare the nitre burning with spray burning. The two differ in the point of attack, the nitre beginning at the apex and the margins of the leaf and very rarely, if ever, on the inner parts of the blade, and the color is lighter.

This is a piece of sloping ground and is at the base of a hill. There is no irrigation above it that I can recall. A little to the south and west of this orchard on the roadside is one of the most remarkable spots of this character that I have met with, not excepting the first one that I recognized and which is represented by Analysis No. 1, Bulletin 155, page 7.

These spots, for there are a number of them, are scarcely worse than some of the land in the orchard where the trees were burning very badly. This soil is actually kept moist by the deliquescent nature of the salts formed. A sample from such a spot in the orchard gave 12.10 percent soluble in water and the notes state that this residue had to be dried at 110° in the air-bath for 12 hours. Another sample gave 12.560 percent soluble in water, and this extract bears a special label "had to dry at 115° for 20 hours to get dry enough to put into the bottle." I am giving these details perhaps *ad nauseum*, but I find that they appear so strange to persons who have never met with such facts themselves as to seem wholly incredible. The analyses of these samples may be their own witnesses.

ANALYSES	LIX Water-Soluble Laboratory No. 791 May 10, 1909	LX Water-Soluble Laboratory No. 823 July 23, 1909	LXI Water-Soluble Laboratory No. 790 May 10, 1909	LXII Water-Soluble Laboratory No. 828
	Percent	Percent	Percent	Percent
Calcic sulfate	55.242	21.249	14.495	4.401
Calcic chlorid	———	———	47.523	28.313
Magnesic sulfate	15.021	14.253	———	———
Magnesic chlorid	11.883	———	4.363	18.801
Magnesic nitrate	———	———	10.792	0.491
Potassic sulfate	———	1.606	———	———
Potassic chlorid	3.005	———	2.114	———
Potassic nitrate	10.001	———	———	2.711
Sodic sulfate	———	35.798	———	———
Sodic chlorid	———	10.607	———	———
Sodic nitrate	4.273	16.395	20.585	45.283
Iron and Aluminic oxid	0.139	———	———	———
Silicic acid	0.436	0.092	0.128	———
	100.000	100.000	100.000	100.000

ANALYSIS	LXIII Soil Laboratory No. 791* May 10, 1909
	Percent
Sand	67.910
Silica (sol.)	3.280
Sulfuric acid	0.760
Chlorin	0.200
Phosphoric acid	0.170
Carbonic acid	2.640
Lime	4.250
Magnesia	2.060
Sodic oxid	0.530
Potassic oxid	0.880
Ferric oxid	3.900
Aluminic oxid	4.400
Manganic oxid (br.)	0.280
Moisture, 110°	3.510
Ignition	5.640
Sum	100.410
Oxygen equiv. to chlorin	0.050
Total	100.360
Humus	0.380
Humus ash	0.382

This is an extremely interesting instance of the occurrence of nitrates. The ground slopes toward a meadow, a part of which has been converted into a reservoir but the land is decidedly higher than the meadow, as it is on the lower slope of a hill. The field along the roadside where one of these spots occurs was in alfalfa; the land was good, and the alfalfa healthy, so that one seems

*The depth to which this sample was taken is not stated. It was probably about three, certainly not more than four, inches.

justified in assuming that no considerable rise in the water table has taken place for a number of years, and further that it is reasonably low.

The ordinary soil analysis shows nothing which we might interpret as indicative of any deficiency or trouble.

Case No. 19—While this number is used to designate a specific locality, it will embrace a number of minor occurrences within a stretch of country about five miles long, lying approximately one hundred and fifty feet above the river bottom. Portions of this mesa are seeped and a drainage system has been put in, with what results I am not able to state, but it is claimed that it has been of benefit.

This section was scarcely more than referred to in Bulletin 155, as only two analyses, one of an alkali, Laboratory No. 595, and the other of the water-soluble portion of a soil, Laboratory No. 588, were given with a very meagre statement of the conditions. These samples were taken in 1907. It is true that attempts have been made to drain the land since that time, and the water conditions have doubtlessly been ameliorated, but this nitrate condition has, in my judgment, become more intense, for in 1909 and 1910 there were many patches of nitrates which could not escape the attention of anyone, and which were not present in 1907; besides, the analyses of samples taken in 1907 are by no means so rich in nitric acid as the samples gathered in 1909 and 1910.

There are many points in regard to which my information is not satisfactory, for instance, it is almost impossible, at this time, to obtain reliable data relative to conditions only a few years ago. The properties have changed hands and the present owners will very often make positive statements about conditions which cannot be substantiated. The fact is that they are so averse to acknowledging ignorance of these things that they prefer to give you such statements as it pleases them to make. The owner of the land which is, perhaps, becoming worse each succeeding year does not like to rehearse his misfortunes, especially if he suspects that you may be a prospective buyer of his or other property in the neighborhood. Many of them feel that it is disloyalty to their community to acknowledge patent facts. This trait, in their judgment, and in that of many others, may be wholly praiseworthy, but it hinders greatly in a study of this sort in which one has, in a measure, to depend upon the testimony of the residents for many facts in the recent history of a section. That there was a period of greater prosperity for this section is attested by the remnants of orchards, fields which a few years ago were productive, abandoned houses now falling into decay, etc. These witnesses to the very poor judgment of former occupants or to a period of better

conditions, are usually dependable, but we must determine which of the two it is.

I believe that there is no doubt but that the settlers of this section suffered many disappointments and that while events showed that they misjudged the difficulties, they had at the time no way of recognizing these difficulties, or of knowing how serious they were. In portions of this section the water plane in 1889 was, according to the information that I have been able to obtain, twelve feet below the surface. In October, 1907, I found it four feet below the surface. How much it had been recently affected by the irrigation of neighboring lands I do not know. Here is a difference of eight feet in the height of the water plane, and why this water did not drain out was not apparent. In 1907 a very considerable area of this land was seeped and there was some nitrate present but not enough to become an easily recognized feature. Drainage has since that date been introduced on a considerable scale and in 1909 and 1910 nitre spots were recognizable in many places. I wish at the present time simply to record the sequence of facts. I will first consider a piece of land, a part of which had been planted to barley and a part to oats. The whole piece measured several acres. Both the barley and oats had been creased for irrigation after sowing. In very many places there were no oat or barley plants between the creases. The seed had never come up, or the young plants had been killed. There were abundant indications that the latter had been the case, whether the former had been or not, but from my observations on other areas I have no doubt but that it, too, was the case here, i. e., that much of the seed did not come up. The plants were confined to the sides of the creases just above the edge of the water. The bottom of the crease or furrow was, of course, free from plants, and the crown between the creases was brown and barren and extremely mealy.

The question of where the water which had raised the water table in the years between 1889 and 1907, eight feet, came from is appropos. So far as I know this rise was wholly due to the irrigation of these lands, in other words, this section does not receive the drainage from other lands higher than it.

I did not attempt to take a sample of this soil, only one of the mealy surface portion. The sample, 981, was taken with an irrigating shovel and I probably took some of the soil as deep as two inches. This sample as taken contained 28.44 percent of its weight, air-dried, which was soluble in water. It is no wonder that the oats and barley died. This is so great an excess of salts that one is tempted to ask whether sodic sulfate or any other relatively innocuous salt would not have sufficed to account for the conditions presented. I will record the facts as I find them, here as elsewhere, without regard to the question of whether they appear

to be in harmony with my views or not. The quantity of soluble salts in this surface, mealy soil is exceptionally high and contains an unusually large amount of organic matter for our samples. In judging this amount and the effects of the salts in this sample it must be borne in mind that it was taken to represent the surface portion only and the fact that I possibly got some portion of the sample at a depth of two inches was an accident due to the fact that I took it with a round-pointed shovel. The great bulk of the sample was made up of the mealy, almost dry, surface portion. This did not form an incrustation of effloresced salts, as we often find where the common white alkali prevails. Professor Sackett tells me that the soil extract made from the surface sample which he took failed to develop azotobacter in his culture medium. They had probably been killed as well as the other plants due to the concentration of the salts. This is not the only sample in which this has been found to be the case. In the case of Orchard No. 2, Bulletin 155, pages 13 to 17, we found this to be true. Samples from the surface of excessively bad portions gave no development of azotobacter, whereas samples from below the surface or at or near the edge of the bad territory gave a very abundant development. It is therefore, quite what might be expected, i. e., to find this ground, so extremely rich in soluble salts, devoidof azotobacter.

The following samples are from the same section of country but not from the same place. No. 590 and 595 are from the same place but 981 is from another, a mile or possibly more north of it. I used the term spots in describing these occurrences in Bulletin 155 and again spoke of the nitrates occurring in almost continuous but irregular areas, but have not deemed it necessary to give analyses of alkalis and soils outside of these areas except in Case 8, as the amount of the nitrates are so unusual that I have deemed it unnecessary. Samples 590 and 595 are from the same piece of land and taken not far from each other on the same date. They were both originally taken as samples of alkalis, as we were studying, at that time, the effects of alkalis and the maximum amount of them compatible with good crops, etc.

The water-soluble equalled in 590, 7.57, in 595, 33.33 and in 981, 28.44 percent. Samples 590 and 595 were collected in 1907 and 981 in 1910.

ANALYSES	LXIV Water-Soluble Laboratory No. 590 Percent	LXV Water-Soluble Laboratory No. 595 Percent	LXVI Water-Soluble Laboratory No. 981 Percent
Calcic sulfate	19.561	9.102	3.651
Magnesic sulfate	11.236	8.076	3.558
Potassic sulfate	1.039		1.034
Sodic sulfate	52.457	56.254	70.746
Sodic chlorid	10.827	22.609	16.109
Sodic nitrate	Trace	2.771	4.854
Sodic silicate	0.247	0.308	
Silicic acid			0.048
Loss	(4.633)	0.880	
	100.000	100.000	100.000

Another sample of soil, 826, taken about one mile and a half south of No. 981, and a year previous, is interesting because the occurrence was a new one at the time. It was on the face of a low bank where they had plowed and scraped out dirt in working the road. I am quite familiar with this road as it is a section in which I have observed the alkali question for going on five years, and I feel quite safe in making the statement that the occurrence was one which had appeared there within a few months, certainly within a single season. I do not know how deep the water table was at this place but the land was so high that seepage would not ordinarily be thought of; in this case, however, the presence of so large an amount of soluble salts, 16.30 percent, will appear to some as indicative of a seeped conditon. In this connection I repeat again the observation that I have not yet found this condition in places where the water table is near the surface of the ground, especially if it is permanently near the surface, but in such places as have an abundant, but not an excessive, water supply. I do not pretend to know all the conditions which are necessary to determine the development of these nitrates, but that water is one of the conditions is very evident. For in ground that is in good condition, with which, ordinarily speaking, no fault can justly be found they, the azotobacter, will develop along the margins of irrigating furrows; again, they are apt to develop near a ditch, even on level ground, and are especially liable to appear on the outside of a ditch bank where the apparently flourish.

Under the caption of Case No. 8, I have given, it appears to me, conclusive proof that neither the alkali, nor the soil, nor yet the ground water contained any nitrates, still the outside of a ditch bank running beside this land, practically running through it, is almost or quite black in color, which color is continuous for considerable distances, and the surface soil is decidedly rich in nitrates. This color is not due to the wetness of the soil, nor to the alkalis, including calcic and sodic chlorid, in the usual use of

this term but to the presence of azotobacter and nitrates which do not come from the adjacent land or the ground water, nor from the water that flows in the ditch, but are developed in the soil, and the controlling factor in this case is the constant and abundant supply of moisture. To some the facts given may not be fully convincing that the nitrates are formed *in situ*—to me they are, but we will give, in the proper place, further proof that this is so. This is true, too, of the sample which we are discussing; the ground is not seeped but there is a ditch perhaps ten feet away which probably furnishes the necessary moisture. I do not know why this had not developed in this place prior to 1909, but it was there in 1909 and I had not seen it there before. This and the next following samples were taken during a shower and I have made no notes of how the samples were taken. They may have been, and probably were, shoveled up hastily as it was not a good time for making notes. The samples were taken to learn the character of these surface salts. This accounts for the high content in water-soluble which amounts in No. 826 to 16.30 percent, and in No. 822 to 32.07 percent. The latter sample, No. 822, was taken a mile or more south of sample No. 826 and near to the edge of an alfalfa field which was in good condition at the time, and so far as I know is at this time. There was, however, a depression immediately south of this which is, at times, filled with water.

ANALYSES	LXVII Water-Soluble Laboratory No. 826	LXVIII Water-Soluble Laboratory No. 822
	Percent	Percent
Calcic sulfate	16.044	7.973
Magnesic sulfate	8.411	7.911
Potassic sulfate	1.074	0.999
Sodic sulfate	49.623	73.105
Sodic chlorid	22.345	9.074
Sodic nitrate	2.394	0.839
Iron and Aluminic oxid		0.040
Silicate acid	0.109	0.059
	100.000	100.000

The territory from which the last five samples were gathered is above the shales which were described and analyses of which were given in Bulletin 155 pp. 28 and 29, Laboratory No. 645, and while this locality is not the one referred to in explaining the occurrence of nitrates in certain waters and in the shales themselves in which I state, "The occurrence of nitrates in the waters and apparently in the shales is susceptible of an easy explanation, i. e., the nitre spots which are only exaggerated instances of a general condition, occur in lands above the shales," it exemplifies the condition described in a most satisfactory manner.

The following analyses of a soil and its aqueous extract will

help to give a fuller view of the general state of affairs in this section. The soil was, of course, strongly impregnated with alkali, and judging from the age of the orchard that occupied it, had been under cultivation for a number of years, not less than fifteen, and probably more than twenty. The water-soluble equalled 6.65 percent of the air-dried soil.

ANALYSIS	LXIX Soil Laboratory No. 588
	Percent
Sand	42.745
Silicic acid (sol.)	26.526
Sulfuric acid	3.187
Chlorin	1.799
Phosphoric acid	0.111
Carbonic acid	1.345
Lime	3.634
Magnesia	2.032
Sodic oxid	4.020
Potassic oxid	1.191
Ferric oxid	3.792
Aluminic oxid	5.483
Manganic oxid (br.)	0.113
Ignition	(4.428)
Sum	100.406
Oxygen equiv. to chlorin	0.406
Total	100.000

ANALYSIS	LXX Water-Soluble Laboratory No. 588
	Percent
Calcic sulfate	22.550
Magnesic sulfate	7.381
Potassic sulfate	2.468
Sodic sulfate	36.168
Sodic chlorid	24.884
Sodic nitrate	6.297
Silicic acid	0.252
	100.000

It is difficult to see how the drain waters from such a section, abounding as this has during the past year in such spots, can fail to be comparatively rich in nitrates. Analyses of two drain waters, and two seepage water were given in Bulletin 155. The two seepage waters were from the base of another mesa, but in this general section of country; the two drain waters were from an entirely different section of the country but one where similar conditions prevailed. We are justified by these facts in assuming

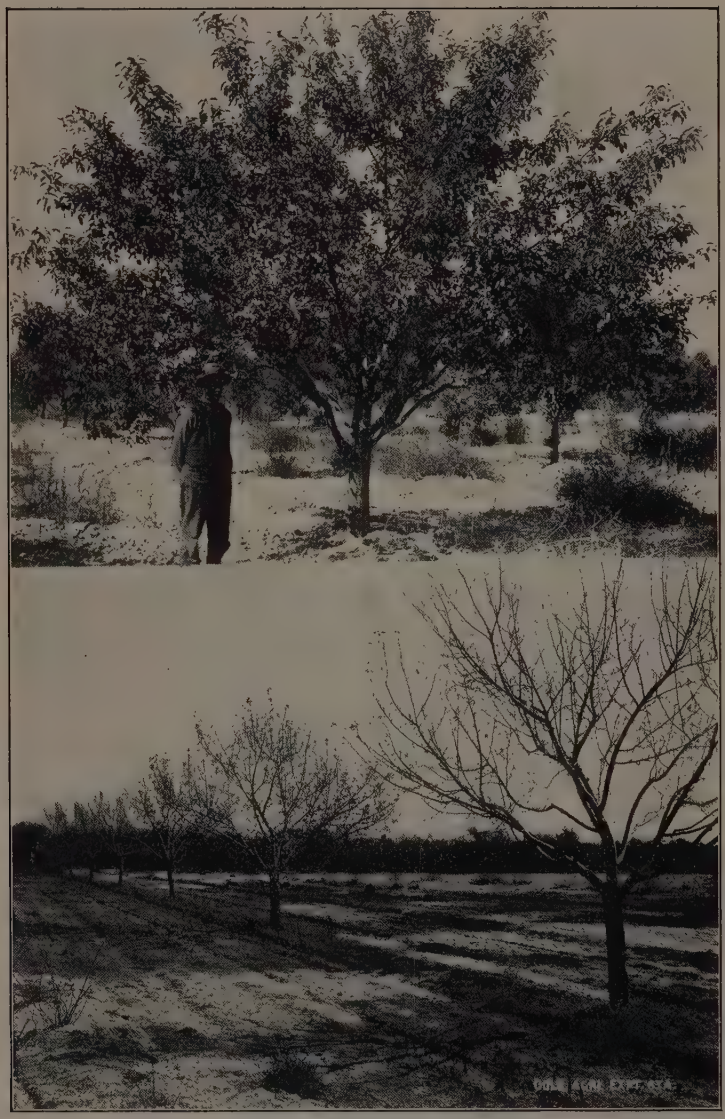

PLATE V.—See pages 62 and 63.

No. 1 is the upper figure

that the seepage and drain water from this area contain nitrates enough to account for all the nitrates which we found in the shales which actually underlie this mesa.

Case No. 20— On page 19, Bulletin 155, I gave a very brief description of the conditions obtaining in the field where our Laboratory No. 680 was collected. I mention it again merely to give the salient features of its condition in 1910, a little over two years after that sample was taken. The land was described as having been an oat field in 1907; the surface was stated to be puffed up and mealy. A sample taken to a depth of two inches yielded 5.42 percent of water-soluble salts salts which contained nitric acid equivalent to 21.719 percent of sodic nitrate. This land was in very bad condition in 1909 and barren in 1910. Of the original 25 acres more than 15 acres (estimated) has been rendered valueless by the combined effects of the seepage and nitrates. What the seepage has not ruined the nitre has, with the exception of possibly ten acres or less. The following four samples were gathered in September, 1909. No. 837 was gathered from a portion of the field where the water had probably done no damage, but where there was much white alkali. The water-soluble equalled 12.96 percent of the air-dried sample. My field notes mention the fact that the brown spots appear on the outer or upper edge of the white alkali. This is a sample of such material as occurs in these mixed spots. No. 839 is a soil sample taken from beneath a brown spot after the surface portion had been removed. The sample represents six inches of soil, five to ten inches inclusive. The water-soluble equalled 12.67 percent. Nos. 841 and 842 are samples of the "black alkali" from different places in the field. The water-soluble equalled 10.30 and 10.40 percent respectively. This land, where these samples were taken, was still in pretty good condition in February, 1908, but in September, 1909, the land was already in bad condition, and in July, 1910 I have entered the note that this land was ruined. There still remained from five to seven acres of winter wheat which was very fine indeed. No samples were taken in July, 1910, because a very heavy rain had fallen only a few hours before my visit.

ANALYSES	LXXI Water-Soluble Laboratory No. 837 Sept. 22, 1909	LXXII Water-Soluble Laboratory No. 839 Sept. 22, 1909	LXXIII Water-Soluble Laboratory No. 841 Sept. 22, 1909	LXXIV Water-Soluble Laboratory No. 842 Sept. 22, 1909
	Percent	Percent	Percent	Percent
Calcic sulfate	1.086	41.538	12.503	8.719
Calcic chlorid	———	3.675	23.624	28.047
Magnesic sulfate	20.124	———	———	———
Magnesic chlorid	———	9.802	3.655	2.952
Magnesic nitrate	———	———	20.699	20.522
Potassic sulfate	1.404	———	———	———
Potassic chlorid	———	2.369	———	———
Potassic nitrate	———	———	4.899	4.021
Sodic sulfate	14.854	———	———	———
Sodic chlorid	26.067	1.589	———	———
Sodic nitrate	36.078	40.258	33.820	35.077
Iron and Aluminic oxid	0.285	0.452	0.323	0.247
Silicic acid	0.102	0.317	0.397	0.415
	100.000	100.000	100.000	100.000

The location of this land is such that we cannot account for the presence of the large amount of nitrates by supposing them to have been brought into the area by surface waters and scarcely by underground flows. The seepage in this case is probably largely due to leakage from an irrigating ditch and in some measure to the excessive use of water by a neighbor, but the acreage from which such water might come is too small to account for the conditions as we find them. This land, like the most of our lands, contains the so-called alkalis.

Case No. 21— This is the same as No. 4 given in Bulletin 155, page 18. The reason for mentioning it is that it presents conditions which contrast quite strongly with the last instances given under the captions of Nos. 19 and 20. This piece of ground has been so dry every time that I have visited it, that it has seemed impossible that the nitrates should develop if I am correct that there is a minimum quantity of water necessary for its most rapid development, and that this minimum is rather high. Without having made any experiments to determine this amount I would judge it, according to my observations, to be above 18 percent of the weight of the soil. The bacteria can, without doubt, survive long and pretty thorough drying, and if a favorable degree of moisture be supplied at any time they are ready to develop. Whether they be able to endure greater changes in conditions than other kinds of bacteria or not is a question that I know nothing about, but unless I am greatly in error in the whole matter, the conditions in the present case become of considerable interest in this discussion. In discussing Nos. 19 and 20, as well as in my statement of the general proposition, I have connected it so closely with that of seepage that some may infer, as I know that some have already

done, that there is no nitre problem independent of seepage even though I have, perhaps, gone almost to a ludicrous extent in digging holes and giving the depth of the water table, the character of the soil and the drainage conditions to show that the death of the trees and other vegetation had not been brought about by an excess of water *per se,* and I have further given analytical data, as it seems to me in superabundance, to show that it is not due to an excessive amount of other salts which we think may be injurious.

I shall deal with this latter subject more fully in another bulletin, wherein I shall try to set forth more facts in detail which pertain to the effects of the presence of excessive water, large quantities of alkalis, and the presence of nitre—for the time being it will suffice for the fair-minded to consider that in the most disastrous cases—and I use this adjective advisedly, granting the reader the privilege of reading into it as much pessimism and prophecy as he may desire—that I have described; have been on land which has been set to orchards for from twelve to twenty-eight years, well drained and otherwise well cared for, in some cases it has been excessively irrigated to combat this very trouble, which shows that in some cases the natural conditions and the intelligent efforts of men have combined to prevent the accumulation of either water or salts leached from adjacent lands, which we have furthermore shown do not contain nitrates, and yet we have recorded the utter destruction of a twenty-seven or twenty-eight-year-old orchard in the short period of six weeks. If this were the only destruction wrought I would not at all be justified in using the language that I have used, or even in presenting the subject, except from its purely scientific side, but it is not a thing which has happened in one piece of land, nor in twenty pieces of land, but in very many pieces scattered over hundreds of square miles—not in patches of a few square feet but in large areas which, though irregular in contour are practically continuous for five, ten or even more miles. While the scientific features of the problem are of primary interest to me and the most of my readers, the magnitude of the land values involved and the questions of the future add reality and an importance to this question which the public has failed to recognize, or recognizing fear to acknowledge. There is a saying the "Fools rush in where angels fear to tread." Perhaps I have done this. Neither my folly nor courage alters the fact that the damage already wrought is immense, and I have elsewhere stated that unless something intervenes—what it may be we cannot forsee—the situation is serious. This is the practical side of the question.

The conditions obtaining in this case are the justification for presenting it as they emphasize the distinctness of this question from those of seepage and alkali. The land is on a hillside with a

south and southwest aspect. Six years or more ago water was stored in a reservoir in the northeast corner of the field. My information is that this reservoir was used for about four years but has not been used within the past six years. The field was in alfalfa four years ago. It was broken up and in 1908, set to apple trees. The area is, I think, 20 acres, possibly more. About four acres of the trees died. This land was reset in the spring of 1909. So good as none of the new trees lived. By midsummer of 1909 the area of dead trees had extended to twice its original size. In 1910 there are from twelve to fifteen acres on which but few trees are living.

Plate VI, lower Fig., a photograph taken Oct. 29, 1910, shows how large a portion of this field is wholly barren, not even Russian thistles or other weeds being able to grow on it. The rows that show in the plate are furrows between the rows of corn planted this season but which did not grow. That the land has been irrigated this season and the last time, at least, with a good flow of water is evidenced by the washing of the soil in the bottom of the furrows. Aside from this one piece of evidence most observers of this crop and the trees would raise the question whether the land had not suffered from neglect at the hands of the manager and for the want of water. I did not attempt to determine the depth of the watre table in this case as there is a deep wash at the west side of this hill not more than a few feet from the corner of this field, and there is, at this place, no water coming in above the bed of the wash. This land is underlaid by a shale at varying depths in different parts of the field. The trouble in this case began prior to 1907, as I was informed, somewhere about the middle of the land shown in the foreground of the plate. I took a sample of the surface soil in March, 1909, and another October 29, 1910, from almost the same place in the field. The former was taken to a depth of two inches, and the latter to a depth of four inches.

The analyses of the water-soluble portion of the two samples follow:

ANALYSES	LXXV Water-Soluble Laboratory No. 759	LXXVI Water-Soluble Laboratory No. 1026
	Percent	Percent
Calcic sulfate	18.986	26.940
Magnesic sulfate	29.771	19.972
Potassic sulfate	1.387	1.109
Sodic sulfate	39.914	43.117
Sodic chlorid	1.474	1.661
Sodic nitrate	8.173	6.631
Ferric and Aluminic oxid	———	0.348
Silicic acid	0.295	0.222
	100.000	100.000

The water-soluble in No. 759 amounted to 8.23 percent of the air-dried mass; that in No. 1026 to 5.277 percent. These samples were taken nineteen months apart. The difference in the depths to which the samples were taken is unfortunate as the reader will be apt to overlook this in comparing them. I found No. 1026 entirely free from chlorin after the third washing, but the sample was rich in calcic sulfate and some difficulty was experienced in washing out the last of it as it was almost impossible to filter the well washed soil. The difference in the amount of water-soluble is less than one might expect, considering the different depths to which they were taken.

Cases Nos. 22 and 23—These are adjoining orchards and ordinarily would be considered as cases of seeped land. I shall say but little about orchard No. 23 for all that may be said of No. 22 is applicable to No. 23, except that No. 22 is a more recent development. The soil of these orchards is mostly a sandy loam but in places this is either underlaid or wholly displaced by gumbo, a calcareous, clayey soil which when thoroughly wet retains water wonderfully well. We attempted to dig a hole in one of these orchards but the ground was so tough that we abandoned digging and tried to force a bar down to water. We were assured before we began that we would not succeed, not only because of the character of the ground, but also because the water was not so near the surface as we imagined. We succeeded in putting the hole down nearly four feet but without striking water; the gumbo was, however, extremely sticky. An idea of the manner in which this soil holds water may be conveyed by the fact, related to me, that shortly after we dug this hole a heavy shower filled it with water which did not seem to pass into the soil at all and was removed apparently by evaporation. That this ground was not always in this condition is proven by the fact that the apple and other fruit trees had lived for thirteen years and made a good growth in this soil. Further, the dying of the trees in parts of this orchard in which these conditions do not obtain shows that the wet, sticky conditions did not kill the trees but are themselves caused by the conditions which bring about the death of the trees. I have elsewhere suggested this because of the peculiar condition met with in the soil, but in this case because it seems to follow directly after the other trouble. The statement has been made in connection with several orchards that while the soil itself was practically a mud there was no proper water table found at depths of six to six and one-half feet. In the present case we did not succeed in digging to a greater depth than a little less than four feet, but the house stands at the edge of the orchard and a little lower if anything than the point where we tried to dig. The

cellar under the house is stated to be about eight feet deep in which water rises and falls with the seasons. From this we found that at the lower edge of this very bad area the water plane was almost exactly six feet below the surface, at the end of the irrigating season. The cellar was dry when dug, now six years ago.

This orchard has taught us quite a number of things. We have been able to observe the death of the trees in a zone at the edge of this bad area just as the brown color extended. There was no trouble during the thirteen years of the life of the trees when no "black alkali" appeared, but as soon as this "black alkali" appeared the trees began to die; some of them began to burn and died within two weeks. From one-half to three-fourths of an acre died between August 18 and October 29, 1910, while other trees not more than twenty-five feet away remained in fine condition. In this case the trouble continued to spread till the end of the season. I did not learn whether there was any relation between the times of irrigation and the virulence of the attack on the trees and the rate of their dying. The manager has recently written to me that he irrigated this orchard about the first of December, 1910, and that the surface of the ground became intensely brown immediately after the application of the water even at the north end.

A hole dug just north of this orchard encountered a little water at four and a half feet, but the shale beneath this, to a depth of five feet more was entirely dry. A tile drain has been laid the entire length of the north side, varying from four to six feet in depth. My information is, that it is entirely dry.

The water is not in the irrigating ditch long enough, during the season, to affect the area in question. I asked the manager of this orchard repeatedly in regard to the possibility of the trouble being due to water and he as often repeated his answer that he could not believe it to be due to this cause. The depth of the water table, as shown by the water in the cellar, six feet, with very little variation throughout the year, supported his view. The water table, as indicated by the water in this cellar on December 28, 1910, was seven feet two inches, giving us a variation of fourteen inches for the year. The accompanying plates from photographs kindly furnished me by Professor Sackett, illustrate the condition of the land and orchard October 29, 1910. Fig. 1 indicates the upper and Fig. 2 the lower figure in the plate. Plate V shows the condition of a Paragon tree which had not been affected at the time the photograph was taken while Fig. 2, Plate III, shows a tree which died between August 18 and October 29. The tree at the extreme right of Fig. 2, Plate V is the next tree immediately east of Fig. 1, same Plate. Fig. 1, Plate V shows no brown areas while Fig 2 shows them very well. Fig. 2, Plate III shows a tree killed since August 18 and entirely denuded of leaves. The

photograph looks southward and shows that portion of the land from which the trees had been removed. There was white alkali showing on a portion of this area at the time the picture was taken but it cannot be distinguished from the sunshine on unstained ground. The white patches in the other figures are due to sunshine. Fig. 1, Plate V looks westward into that portion of the orchard not yet affected. Fig. 2 of the same plate looks eastward across the affected area. Fig. 2, Plate III looks southward across the worst portion of the land while Fig. 2, Plate IV looks northward toward the still healthy portion of the orchard as the background shows. It will be noticed that the third row and even some trees in the second row were in good condition at the time the picture was taken, October 29, 1910, but they died so rapidly that in the spring of 1911 five rows of these trees including the row of dead trees in the foreground were dug up and by June four more rows of trees had been killed.

The following are analyses of white alkali, water-soluble portions of this soil, and the ground water.

Laboratory No. 996, white alkali within bad area, 18.67 percent soluble in water.

Laboratory No. 1027, white alkali within area where trees were killed, 22.71 percent soluble in water.

Laboratory No. 1029, soil from orchard designated, Case 23, surface of soil brown, trees dying, 11.44 percent soluble in water.

Laboratory No. 999, water taken from cellar August 18, 1910, total solids 14,230 p. p. m.

Laboratory No. 1040, water taken from cellar December 28, 1910, total solids 17,561 p. p. m.

Laboratory No. 1028, surface soil, composite sample, one to two inches deep. No white alkali, trees dead, 3.11 percent soluble in water.

Laboratory No. 1046, brown, mealy soil four inches deep, composite sample, 1.29 percent soluble in water.

Laboratory No. 1041, water collected from sixteen-foot hole January 6, 1911, total solids 22,100 p. p. m.

ANALYSES	LXXVII	LXXVIII	LXXIX	LXXX
	Water-Soluble Laboratory No. 996 Aug. 18, 1910	Water-Soluble Laboratory No. 1027 Oct. 29, 1910	Water-Soluble Laboratory No. 1029 Oct. 29, 1910	Water-Residue Laboratory No. 999 Aug. 18, 1910
	Percent	Percent	Percent	Percent
Calcic sulfate	7.607	8.979	18.873	4.942
Calcic carbonate	———	———	———	4.536
Magnesic sulfate	31.447	24.794	36.407	19.604
Potassic sulfate	3.986	0.859	1.330	0.719
Sodic sulfate	52.776	56.877	28.816	59.415
Sodic chlorid	4.137	4.332	8.235	7.214
Sodic nitrate	———	4.017	6.094	3.688
Iron and Aluminic oxid	———	Trace	0.076	0.085
Silicic acid	0.047	0.142	0.169	0.117
	100.000	100.000	100.000	100.000

ANALYSES	LXXXI	LXXXII	LXXXIII	LXXXIV
	Water-Residue Laboratory No. 1040 Dec. 28, 1910	Water-Soluble Laboratory No. 1028 Oct. 29, 1910	Water-Soluble Laboratory No. 1046 Feb. 1, 1911	Water-Residue Laboratory No. 1041 Jan. 11. 1911
	Percent	Percent	Percent	Percent
Calcic sulfate	10.946	41.451	44.886	6.208
Magnesic sulfate	41.809	6.020	0.081	37.659
Magnesic chlorid	———	9.296	8.768	———
Potassic sulfate	1.012	———	———	1.210
Potassic chlorid	———	1.021	2.727	———
Sodic sulfate	33.267	———	———	51.876
Sodic carbonate	———	———	———	2.422
Sodic chlorid	7.726	19.234	15.847	0.556
Sodic nitrate	5.083	21.377	26.640	none
Iron and Aluminic oxid	0.080	1.203	———	———
Silicic acid	0.077	0.398	1.051	0.069
	100.000	100.000	100.000	100.000

This orchard presents three distinct problems—seepage, alkali, and nitre, which questions present themselves in the following forms, First, has the water collected in this area to such an extent as to make the land unfit for ordinary agricultural purposes unless it be drained? Second, is the concentration of the so-called alkalis so great that they alone have caused the difficulties? Third, have the nitrates brought about this soil condition and also caused the death of the trees?

I simply state the facts as we have found them and as they are exhibited by the analyses given. I long ago made the assertion that Colorado has no alkali question which does not resolve itself into one of drainage, and again, that I have not seen any crop seriously injured by alkali alone though I have seen some crops drowned out. Even soils that are very rich in the sulfates of soda, magnesia and lime will, if they be not at the same time all too wet, grow crops, sometimes good ones. In these cases it is the water rather than the alkali that does the damage. This is not the case with nitre, it kills trees and other plants in a characteristic

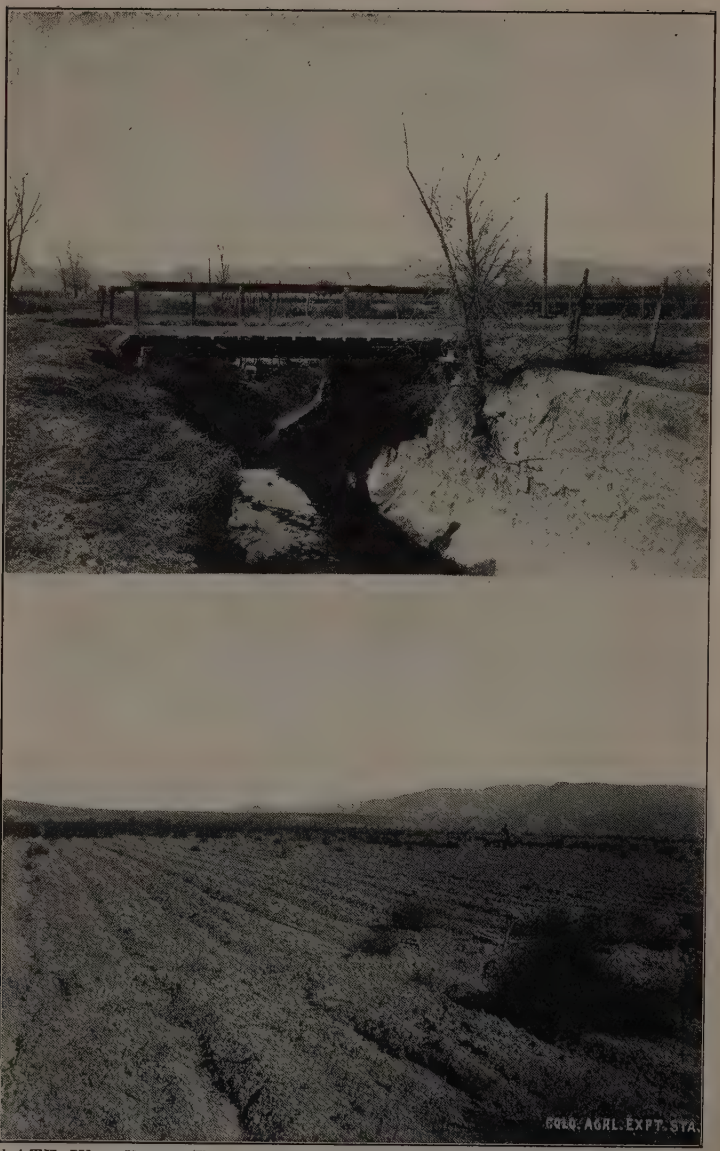

PLATE VI.—Upper Fig. represents wash mentioned in Case 13, p. 35. See also p. 60.

No. 1 is the upper figure

way when there is no excess of water, as we have demonstrated by experiments.

In regard to the water question in this case the facts are not clear. I have given the depth of the water plane as seven feet and stated that the annual variation above this is probably not more than ten or twelve inches. These statements are based upon the heighth of the water in the cellar of the house standing at the lower edge of the low portion of this land and also upon the results obtained by digging a hole nine feet deep and extending it by means of a post-hole auger to sixteen feet when the water rose to within seven feet of the surface. These figures were given to me by the manager of the property and are entirely reliable. The water at sixteen feet is evidently under some hydrostatic pressure but not enough to force it nearer to the surface than seven feet. The cellar referred to is a large one, 25x50 feet, and I think gives the true heighth of the water plane. These statements are not made to indicate that the surface of the land is not wet, for it is, but to indicate that the wet condition of the surface is not due to a high water plane but to surface waters. This water near the surface is probably none other than irrigation water, it is certainly not due to the run-off from heavy rainfalls, and is not due to leakage from an irrigating ditch to the north of the orchard. A salready stated holes or wells dug north of the orchard but south of the ditch did not show much water and a trench from fou rto six feet deep, dug the whole length of the orchard developed no water. The only water that could collect on this ground would be that used in irrigating about twenty acres of land. The orchard must no wbe fifteen years set and so the concentration of salts by washing and evaporation must have been going on this long at least. During this time, however, some may have been carried away by run-off waters.

Laboratory No. 996 is a sample of white, effloresced alkali and contained no nitrates. No. 1027 is a sample of surface soil and alkali taken two months later than No. 996 from another, but a very bad portion of the land, in my judgment, the worst. No. 1029 is a sample of alkali and soil taken from an adjoining orchard indicated as Case No. 23 which is wholly neglected by its owner and no further mention will be made of it. No. 1028 is the water-soluble portion of a soil sample taken October 28, 1910, one and one-half inches deep. There was no white alkali at this place and the soil was in fine condition, but the trees were dying, the water-soluble in this sample was 3.11 percent but the nitrates present were equal to 0.676 percent of the sample. No. 1046 is another sample of soil taken Feb. 1, 1911, about four inches deep. This sample was taken west of the bad ground by taking smaller samples, uniting them and cutting down the mass to a convenient size. The water-soluble equalled 1.25 percent of the soil and the nitrates

amounted to 0.333 percent of the air-dried sample. No. 999 is the residue obtained by evaporating a sample of the water taken from the cellar, August 1910, to dryness. The residue equalled 996.1 grains per imperial gallon or 14,260 p. p. m., while No. 1040 is a similar sample taken December 28, 1910 carrying 1229.27 grains per imperial gallon or 17,561 p. p. m. These samples cannot be taken as actually representing the ground water owing to the fact that concentration due to evaporation must have taken place. The dimensions of this cellar as stated are 25x50 feet and while the house is built over it the cellar windows were open and we are uncertain in regard to the changes in it principally due to concentration. The first water observed in this cellar came in in the winter of 1908-1909 or about eighteen months before the sample 999 was taken and the analyses present the following results: the white alkali which had effloresced contained no nitrates; the white alkali mixed with some soil from slightly higher ground contained some nitrates, one twenty-fifth of the weight of the water-soluble; but the soils which would ordinarily be considered as free from alkali contain nitrates equal to one-quarter of the weight of the water-soluble.

The present owner of this land has put in upwards of 15,000 feet of tile drains. I saw about 7,000 feet of the trenches open in the very worst part of the land. The surface of the land was muddy as though they had recently had a heavy rain or the land had just been irrigated, the second spit was decidedly dryer than the first and while there was some water in the bottom of the trench, here and there filling the depressions made by uneven digging, by far the largest portion of it was entirely free from running water. I was very much surprised at the small amount of water appearing in so great an aggregate of trenches. It should, however, be stated that water flows out of such land with exceeding slowness. The fact was that the very surface of this bad land was the wettest portion of it and my impression is that this was always the rule with it. The land at the north end of the orchard is dry and, as previously stated, I was informed by two men, both interested in the success of the work, that the drain trench, from four to six feet deep, developed no water whatever. The effect of ground water upon the trees depends upon the depth at which the roots actually feed as well as upon the heighth of the water plane and the capillary power of the soil. I saw this trench when it was partially dug and I called the owner's attention to the fact that it was rarely the case that the roots were more than ten inches deep, though we occasionally found them, small fibrous roots, fourteen inches deep. The manager informs me that some of the trees in this section of the orchard burned in the autumn of 1910 which seems to be very probable as they are practically dead in the

spring of 1911, in fact a number of trees have been dug up in this portion of the orchard, just how many I do not know, but all of the trees shown in our photographs taken in October, 1910, seventy-five of them, have been removed, but by June 3, 1911 many more trees, nine rows in all, back from the foremost row in Fig. 2, Plate IV have died since August 18, 1910. All of this land is in good physical condition, mellow, well cultivated and free from water.

The white alkali collected in August, 1910 shows no nitrates, that collected from a very bad spot, in October, shows a rather small percentage, 4.017, and as this was surface alkali and soil it does not necessarily indicate a large aggregate amount. The samples of soil taken where there was no white alkali, while giving a low percentage of water-soluble, showed the presence of very large amounts of nitrates, 21.377 and 26.640 percent. While the trees did not die last year, 1910, where these samples were taken, they did die in May of 1911 as soon as the trees put out their leaves.

All of these trees and all others referred to through this and previous bulletins as having been killed by nitre, die in the same manner, with the symptoms produced by the direct application of sodic nitrate.

The water samples in this case are particularly interesting. The samples taken from the cellar, one in August, the other in December, 1910, are both quite rich in nitrates. The richer one of the two carrying approximately one and a third tons per acre-foot of water. The important question is whence these nitrates? The water had begun to come into this cellar about twenty three months prior to the taking of the last sample and the significance of the results depends upon the answer given to this question. The natural, and in this case, correct answer is unquestionably from the surface. The sample of water, No. 1041, taken from a hole sixteen feet deep in all, is very much richer in total solids but contains no nitrates. I take it that this represents the ground water proper of the section and agrees with the ground water proper of other sections showing that the nitrates are not transported to the affected areas by this means.

The destruction of this orchard has proceeded very rapidly. It began in the early summer of 1910 and at this time, June, 1911, almost the whole of a fifteen-acre orchard has been destroyed.

Case No. 24.—This is a very interesting occurrence. The land was sown to sorghum in the summer of 1910, but the crop was a complete failure. There is a large irrigating ditch running possibly six hundred feet to the north of it. The land is somewhat low but there is an orchard close by, in fact is immediately south and east

of it and without knowing the actual difference in level I would estimate it as not greater than two feet. The field immediately north of this property was in beets, which were very poor indeed. This fact is mentioned to indicate that the people still considered it as tillable ground. The question of seepage is of course suggested by its position, but I dug shallow holes three to three and a half feet deep on different occasions without striking water. I was surprised that the water plane was so deep as three feet, but it was evidently deeper. I expect to give in a subsequent bulletin the best possible proof that beets will grow well and yield beets of fine quality with the water plane much nearer the surface than this, and I have seen a fine growth of sorghum on land in which the drainage ditches were not as deep as this. While I willingly admit that in my judgment the people did unwisely to choose these pieces of land for cultivation, they probably did not believe that the land was seeped at the time of planting or was likely to become so during the season, and as I have already indicated, I found no reason for thinking that the water plane was at any time less than three feet below the surface. I dug one of the holes referred to in June, the other in September, 1910. The general conditions that prevail are as I have just described them, but these alone would scarcely have induced me to have made mention of this land, though it is one worthy of study in this connection.

Circumstances enable me to give a few facts pertaining to the effects of flooding. I stated in connection with Case No. 8 that the owner had irrigated excessively till, in his own language, he had "washed the ground white" in expectation that by so doing he would correct the evil. We had, however, no results except the continued bad condition of the land to indicate the effects. Further, I showed that the drainage of his land was ideal. Again in connection with Orchard No. 3, described in Bulletin 155, I stated that the owner of that orchard had treated some of his land in the most drastic manner in an endeavor to correct this difficulty by washing. This party had run a furrow with a turning plow, followed with a subsoil plow and turned into the furrow one hundred inches of water but without any satisfactory degree of success; this statement is very conservative. The last time that I saw this man's orchard it and some of his other land was in a very bad condition. This flooding had leveled the land but it had not removed, if it had indeed alleviated the trouble for any considerable time.

I can, fortunately, present the effects of flooding in removing the salts and benefiting the soil in this case. I chanced to be in this section of the state on the 12th of August, 1910, when, due to torrential rains, the piece of affected land was flooded for about five hours. The flood waters which swept acress it were several inches deep. I learned that about a week subsequent to this another

flood, due to the same cause, covered this land to a depth of two feet and that it was twenty-four hours before these flood waters had entirely disappeared. The flow of these waters, as indicated by the straw, weeds and other debris lodged on the posts and fence wires, was evidently strong, and the depth assigned, i. e., two feet, was probably correct; furthermore it had left very little or no sediment. I had taken a sample of the mealy surface soil on June 6, 1910, so I was glad for the opportunity to obtain a sample of the surface soil from as nearly the same place as I could locate it from memory, on September 25, 1910, not more than thirty-five days after the last flood. On this date I dug a second hole to see how near to the surface the water plane might be, and as stated before it was not within three feet either in June before the floods or in September after them, so the drainage of this land must be reasonably efficient. I may add that the soil at this place was sandy to the depth that I dug, while that of the beet field north of it was heavier, inclining to clay.

ANALYSES	LXXXV Water-Soluble Laboratory No. 956 June 6, 1910	LXXXVI Water-Soluble Laboratory No. 1038 Sept. 25, 1910
	Percent	Percent
Calcic sulfate	7.535	14.126
Magnesic sulfate	12.130	16.097
Potassic sulfate	3.154	2.777
Sodic sulfate	59.793	58.432
Sodic chlorid	13.361	6.934
Sodic nitrate	3.817	1.296
Silicic acid	0.210	0.338
	100.000	100.000

The water-soluble in No. 956, taken in June was equal to 15.35 percent of the air-dried sample, that in 1038, taken in Septemper equalled 9.533 percent and the nitrates, as sodic nitrate, equalled 0.582 and 0.123 percent of the respective samples. It is really an accident that we are able to give these data relative to the effects of these floodings and while they are far from complete they may serve to give us some idea of what we may expect to accomplish by trying to wash the soil, i. e., it will be a much more difficult problem in practice than it is in theory. It would have been very interesting to have been able to determine the distribution of the nitrates in this land immediately after the second flood and to have determined the rate a which they made their reappearance at the surface, for a rapid evaporation must have taken place from the surface of this land at this season of the year. One, however, would think that the flowing of such a volume of water over this land, as occurred on these two occasions, would have extracted and removed the nitrates rather than to have carried them

down into the soil, for it is to be remembered that this land was covered several inches deep by a mass of water moving at a rather rapid rate for five or more hours about August 12, and again about August 20, to a depth of two feet for twenty-four hours. How much nitrogen as nitrates this flood water may have contained I do not know but it could not have been any relatively large quantity. The waters of a reservoir used in irrigating this section of country contained only a trace when last analyzed, now several years ago, and the return waters as represented by a sample of river water analyzed at the same time contained 1.5 p. p. m. Further, this water flowed off of and did not evaporate on this land, so I do not think that the question of transported nitrates is to be considered. The sample taken in September indicates, so far as it is worthy of consideration, that these floods removed approximately four-fifths of the nitrates present as indicated by the sample taken in June.

Case No. 25—This case is given because it presents an example of drained land. The area is twelve acres; it is much longer than wide, the west and south sides being represented by an irregular curve, the field being bounded by a low hill, along the flank of which runs an irrigating ditch, but its supply of water is not good so it is often dry. The owner thought that the bad condition of the land was due to an excess of water. It is now something over five years ago that he put in three lines of tile drain, from four to six feet deep. I have no map of this drainage system but two of the lines, I was informed, run lengthwise of the field for its whole length, and the third one is a line run with the idea that it would intercept the water that leaks from the irrigating ditch and deliver it into the main drains. I do not know the depth of the water table, but I do not think that it is at any place materially above the depth of the drains, i. e., four feet. This land has now been planted to beets for five years in succession and the owner has never harvested a full crop off of all of the field, and for the past three years he has had so good as no crop at all. In October, 1909, I made a note to the effect that from one-fourth to one-third of the field was absolutely devoid of vegetation, even of weeds. I visited this field several times during the season of 1910, and if there was any difference the conditions were worse than in 1909, but they were very bad in both years and the crops were practically failures. Two roads intersect at the northeast corner of this field. The field east of this one and across the road was also planted to beets, the stand was in places poor, the ground brown and mealy; the beets were, as a whole, poor. The field northeast of it was not cultivated, its surface was brown and mealy, but the common sunflower was growing in spots and was very luxuriant. I took two samples of soil about three inches deep, one near the south end and the other

from the north end, on October 11, 1909. The surface at this time showed nothing unusual as a rainfall of 0.83 of an inch had fallen three days before, on the eighth of the month. The surface at this time was not muddy or wet. The sample from the southern part of the field, Laboratory No. 867, contained 2. 564 percent; the one from the north end contained 3.315 percent of material soluble in water.

ANALYSES	LXXXVII Water-Soluble Laboratory No. 866 Oct. 11, 1909	LXXXVIII Water-Soluble Laboratory No. 867 Oct. 11, 1909
	Percent	Percent
Calcic sulfate	28.672	32.729
Magnesic sulfate	14.156	11.468
Potassic sulfate	4.345	3.495
Sodic sulfate	28.779	18.150
Sodic chlorid	17.197	28.256
Sodic nitrate	6.435	5.410
Iron and Aluminic oxid	0.162	0.070
Silicic acid	0.254	0.422
	100.000	100.000

We have in each of these samples essentially 0.16 percent of the top three inches of the soil consisting of sodic nitrate or its equivalent in other nitrates. Even beets have not grown in this soil for four years.

Case No. 26—This is as typical a location for seepage as I think can be found anywhere, not excepting Cases Nos. 22 and 23. The difficulty here has been unhesitatingly designated by the double term seepage and alkali by all local parties concerned up to the present time. The configuration of the country at this place is that of a flat tract bordered on either side by rising ground, the flat section varying in width up to two hundred paces or more, through the central portion of which runs a drainage ditch three to four feet deep and about five feet wide. The portion of this higher strip of land in consideration is about twenty feet above the surface of the lower portion and from twenty-three to twenty-five feet above the bottom of the drainage ditch. Persons really familiar with drainage problems in Colorado will not be misled by the apparently simple condition stated above. In this case borings showed that the water table, in the lowest portion of the cultivated area, was, in November, five feet below the surface, and that the water table at a distance of six hundred and fifty feet south of the drainage ditch was only one foot above, while the surface of the ground at this point was six feet above the bottom of the ditch. As elsewhere stated we will subsequently show that the beet will thrive, producing a fair crop of excellent beets with the water table much

nearer to the surface than this. Borings to a depth of six feet and more at points more remote, failed to reach the water plane. Though the water plane at the lower limit of cultivated ground was five feet below the surface the soil was wet at a depth of two to four inches. The highest portion of this tract is the southeastern corner. The slope is from this portion, north and west to the drainage ditch. The central portion of this strip of land was planted to beets in 1908, 1909 and 1910, but we do not at this time intend to say anything about the beets nor about the land planted to beets, but will consider only the cultivated land west of this. I regret that I have no photograph of this land, for it is exceedingly difficult for any reader who has not actually seen these things to understand even the most faithful description or to have any adequate appreciation of the facts. In 1910 this land was planted to sorghum. There was here and there a little of it that came up but for the most part it was a complete failure, the land being entirely bare except along the irrigating furrows or lateral where, at the margin, showing the limit of the running water, a few small, stunted plants survived. These plants were not more than a few, from three to eighteen, inches high. I took a sample of this soil on November 2, 1910, weighing about forty pounds, and to depths varying from four to six inches. This sample was taken for experiments in incubation, but a preliminary test showed that the soil extract gave very unsatisfactory results, in fact, it was a failure. The azotobacter seemed to have been killed. The water-soluble portion of this soil equalled 4.518 percent of the air-dried soil. A nitric acid determination made on this sample corresponded to sodic nitrate equal to 38.867 percent of this water-soluble or 1.756 percent of the air-dried soil, being at the rate of 70,240 pounds of sodic nitrate per acre-foot; or restricting the calculation to the top six inches actually taken, we have 35,120 pounds, or 17.56 tons per acre, a degree of concentration which is very difficult for those who know nothing about this matter to believe possible.

The water-soluble in the following sample, 1024, equalled 5.54 percent.

ANALYSIS	LXXXIX
	Water-Soluble Laboratory No. 1024 Nov. 2, 1910
	Percent
Calcic sulfate	18.377
Calcic chlorid	18.740
Magnesic chlorid	12.030
Potassic chlorid	1.882
Sodic chlorid	4.550
Sodic nitrate	32.997
Iron and Aluminic oxid	0.115
Silicic acid	0.219
	100.000

It is no wonder to me that the soil was mealy and barren and that our culture experiment showed no living azotobacter. The desirability of a series of nitric acid determinations as well as that of the total nitrogen in samples of such a soil taken at stated intervals is evident, but it has not been and scarcely will ever be feasible to prosecute this work in such detail in the field; there are other difficulties besides the remoteness of the locality from the laboratory. Had I forseen the developments that took place in this land in 1910 I could have arranged matters better. This is all that I wish to say about this case at the present time. I may say something more at a future time.

Case No. 27— This is a sample of earth taken from the roadside near a neighboring town. A vertical face of earth two and a half to three feet high left in working the road, as well as the flank of the road were decidedly brown and looked moist and oily. An irrigating ditch runs about sixty feet north of this point, the bottom of which is between four and six feet above it. There was no undue amount of moisture either at this point or on the other side of the road to indicate leakage from the ditch. The earth is a red, gypsiferous and somewhat sandy clay. The sample was taken from the surface, but a portion of it may have been more than an inch deep. The N_2O_5 present equalled 1.079 percent of the air-dried sample.

Cases Nos. 28 and 29—In this investigation only two occurrences of nitrates have been met with which must be considered as owing their origin to leaching from the soil. How far the nitrates in these two cases may have been transported is, as a fact, wholly unknown.

In the case which I have myself seen they probably came from the immediately surrounding country, as the line of hills about the place is not far away and the occurrence is clearly a surface one. These two occurrences are shallow wells, one of them twenty-seven

feet deep, the other said to be forty feet deep. I have not seen the latter, the water of which was sent to me. We had a little over two litres of water to evaporate down. It was a mistake that we adopted this method of procedure but it was too late to change it when this occurred to me. The water was not a fresh sample when we analyzed it. The total solid equalled 560.8 grains per imperial gallon, 8,012 p. p. m. This water is yellow in color, has a bitter taste, foams strongly when poured or aigtated and had no odor though the sample was old when its container was opened.

The following analysis has been calculated to one hundred:

ANALYSIS	XC Water-residue Laboratory No. 1202
	Percent
Calcic sulfate	35.926
Calcic chlorid	4.348
Calcic carbonate	5.105
Magnesic carbonate	4.095
Magnesic nitrate	44.939
Potassic nitrate	1.870
Sodic nitrate	3.717
	100.000

This analysis shows that the salts in solution are principally calcic and magnesic salts in which magnesic nitrate is particularly abundant. I know of this well only by correspondence . It was the only well in the neighborhood yielding such water, other wells near by yield sweet water.

The other well water to which I refer is also yellow. Its taste is at first cooling, afterwards bitter. It, too, foams on agitation or pouring. The well is twenty-seven feet deep, the water was encountered at the depth of twenty-three feet. The ground yielding it was described as one foot thick; no water came in below this. There was at the time I visited this place four feet of water in the well, i. e., the well was filled up to the top of the water-bearing zone. The well was not curbed except in the upper portion, but was provided with a ladder so that it was easy to go down into it. This well was sunk through a somewhat mottled clay. I took the mottling to be due to aggregations of calcic carbonate. This clay was tenacious enough to stand without peeling off or sloughing. There was no water entering above the twenty-three-foot point and no indications that any water had ever trickled down the sides. The owner has prospected his ranch for water by boring holes from eighteen to twenty-eight feet deep, without success. He has even dug a fifty-foot well which proved to be a dry one. This well is sunken for the most part in Niobrara shales. A little water, apparently a little pocket, was met with at a depth of forty

feet. This was said to have been good water but there was no quantity of it. The well, with this exception, was dry when dug and is still dry. The striking of water in the first well seems to have been an accident. The flow is not strong and comes from the direction of the higher land. The owner stated that one man could not pump the well dry but that two men taking turns could pump it out. The water is unfit for any use, even for irrigation. There were a few hills of corn near the well which had been watered with this well water; the corn was burned and I doubt whether it will survive. There were also some onions which did not show any effects of it. This well is near the owner's house and on ground sloping to the south. The land which the owner prospected for water by borings is lower and at times is flooded by rain water. The surrounding country is not irrigated and the rain fall is not sufficient for the growing of crops. The owner, who is holding the land in the hope that sometime it will be brought under irrigation, stated that he had not gotten enough out of his crops to pay for the labor expended on them. The source of the nitrates contained in this water is unquestionably, I think, the higher lying surface soil to the north of this place. Why the water should be confined, as it apparently is, to this particular area is not evident. There is nothing in the contour of the country to suggest a reason. The first sample of this water that I had, one which was sent to the Station by the owner, contained 1819.5 grains per imperial gallon or 25,993.0 p. p. m., the sample which I collected myself and shipped in glass gave 1692.6 grains per imperial galon or 24,180.0 p. p. m.

ANALYSIS	XCI
	Water-residue Laboratory No. 1077
	Percent
Calcic sulfate	9.553
Magnesic sulfate	56.650
Potassic sulfate	0.769
Sodic sulfate	6.142
Sodic chlorid	3.266
Sodic nitrate	22.480
Iron and Aluminic oxid	1.140
	100.000

The question of the existence of brown spots here would seem to be excluded. Brown spots of course are taken as a positive indication of the presence of nitrates and of azotobacter. Such a concentration of nitrates in surface waters like these calls for a most extraordinary supply of nitrates or a very long period of concentration and the separation of the accompanying "alkali" salts. The activity of the bacteria is conditioned by temperature, moisture

and a neutral or an alkaline medium. The temperature and alkalinity prevail in this section and the only factor which is lacking is the moisture to bring about the formation of nitrates. The correctness of this view is indicated by the occurrence of the brown, greasy-looking spots along the irrigating ditch in a neighboring section of the country, where the land is similar though it is still native prairie. The conditions are not well enough known to justify definite assertions pro or con in these cases. I have not permitted myself to make any prophesises but simply to record the facts as I see them. It would, however, be very interesting to be able to watch the developments in this section for five years if it could now be supplied with an abundance of water for irrigation and we could grow a series of crops on these lands. This experiment, while altogether too big a one to be undertaken by an individual, will in all probability be made and while I cannot hope to be able to study it in detail, I do hope to be fortunate enough to be able to follow it in a general way. It will certainly be instructive to those who shall see it.

DISCUSSION

I have given a large number of cases but each case, with very few exceptions, represents different conditions—not only different from one another, but different from the conditions given in Bulletin 155. I have endeavored to give different conditions and at the same time widely separated localities and samples representative of large areas. The aggregate area described in Bulletin 155, was between eighty and one hundred acres. The area described in this bulletin aggregates more than three hundred acres, and does not include any of that described in Bulletin 155. This is only a very small part of the total area involved in the state. So far as its distribution throughout the state is concerned the areas given represent nine counties, extending from the Kansas boundary to that of Utah and from the Cache la Poudre to the Arkansas river, and even further south, to the New Mexican boundary.

The total percentage of the irrigated or cultivated lands affected by this trouble, to the extent of the instances given, is more considerable than we might wish, but it is not a large percentage of the whole, still if we consider it in square miles and bear in mind the value of the lands affected, as estimated by the owners, it becomes a very serious matter. The four hundred acres described in this and in Bulletin 155 are representative of large districts, I think that as a very conservative estimate we may state the districts affected as aggregating from three hundred to four hundred square miles. In a large portion of this territory the conditions are very bad. The most serious feature is that these very bad portions may only represent extreme developments of a general condition which

exists in our soils which only awaits the occurrence of some optimum condition for its excessive development. One of the factors in this optimum condition is an ample and continuous supply of moisture.

The question of the influnece of the character of the soil has been frequently raised since the publication of Bulletin 155. The wet condition of two of the soils described in that bulletin tended to leave the impression that the whole trouble might be due to water, especially in the minds of readers who might consider the wet, muddy condition of the soil the only cause for the death of the trees, and not to consider this condition itself as the result of conditions other than the presence of water. It was distinctly and repeatedly stated in Bulletin 155 that the water in these cases was not free so as to form a water table at depths of six to six and a half feet. In the case of Orchard No. 3, I stated that the land where the sample of mealy, surface soil was taken was sandy and that the ground was only fairly moist at a depth of six feet. In Cases 5, 7, 8 and 9 we again have sandy and in part light clayey loam with sandy subsoils, and no excess of water at depths reached by the roots of the trees. In the Cases of Nos. 8 and 9 we have excellent drainage. In these cases, especially in the latter, the trouble can in no manner be attributed to an excess of water. Still Case No. 9 was one of the most severe ones that I have yet seen, though it is underlaid by a stratum of gravel at a depth of from five and one-half to eight feet. The same is true, in different measures, of Cases 10, 11 and 12. The soil in Case No. 10 is decidedly sandy with a stratum of coarse granitic gravel at a depth of only three feet and yet this land is in such bad condition that the owner has not yet, after repeated attempts, succeeded in getting his fruit trees, peaches and pears, to grow. In Case 12 a beautiful orchard has been destroyed outright in one season. This point is not a matter of opinion but one of fact, and for this reason so many cases, to which Cases Nos. 16 and 20 might be added, have been given. The conclusion is evident that the trouble is not due to the presence of an excess of water, nor to the character of the soil for these sandy soils have shown it to as great a degree as heavier clayey soils of which Cases Nos. 6 and 12 may be cited as examples. No. 6 is an especially bad case, but the results were no worse than in Case 9—they could not be, for two and one-half acres of large trees were killed within a few weeks. The attack in Case No. 6 was not so violent nor did it involve so much ground at one time.

The trouble is not to be attributed to ordinary alkali. In Case No. 8 a part of the orchard is free from the nitre but is rich in ordinary alkali; the trees have died only in the nitre area. There are many orchards scattered throughout the fruit growing

sections which have been planted on ground rich in alkali, which are in good condition. Nearly every case cited in which an orchard is involved is one in illustration of this fact. Cases 5, 6, 7, 9, 11, 12 and 21 were old orchards, from fourteen to twenty-eight years old, in which the trees had thriven till within a few weeks before their death. The soils in these orchards are not richer in alkalis now than they have been in years past, nor richer than the soils of many other orchards which are still in a flourishing condition. Water does not kill so quickly nor in this manner.

The trouble in the cases of orchards is not at all related to the age of the trees, for trees of all ages have been killed. Older trees with large root systems seem to be more readily affected than younger trees but I have seen a nine and an eighteen-year-old tree standing within twenty-five feet of one anotner attacked and killed in practically the same time.

This trouble has spread very rapidly since the summer of 1909 when I first observed bad attacks in orchards. Orchards Nos. 1, 2, 3 and 4, mentioned in Bulletin 155, had been observed previous to that time, but during the past year, 1910, I have seen many orchards, distributed over a wide area, seriously injured. In former years I have seen no injury done in May or early June, but this year, 1911, the damage already wrought is large and the outlook is very ominous.

Orchard lands are by no means the only lands in which this trouble occurs, other lands are as badly affected as are the orchard lands, but orchard lands are conspicuous because of dead or dying trees, or of vacancies caused by the removal of dead trees. Cases 19, 20, 24, 25 and 26 are examples of ordinary cultivated lands.

Apple trees have been mentioned so nearly to the exclusion of others that one might think that the apple is the only tree or plant that is killed. This is not the case. The following trees and other plants have been noted: the apple, pear, peach, plum, apricot, cherry, quince, maple, cottonwood, ash, currant, grape, corn, tomato, bean, pumpkin, cantaloupe, pea, elm, willow, Lombardy poplar, Carolina poplar, sorghum, oats and barley.

I have made no experiments in addition to those recorded on pp. 43 and 44 of Bulletin 155, to demonstrate the effect of nitre on apple trees. The results of those experiments were stated as follows: "The effects were in all respects similar to those produced in the affected orchards, the beginning and progress of the effects, the killing of the leaves, the throwing out a few whitish-yellow leaves, their speedy death and the appearance of the bark and wood after death, were identical. An application of large quantities of salt proved injurious but did not produce these effects." The experiments, eight of them, were concordant and conclusive.

The only new thing that I have noticed during the past year in the deportment of these dying trees was their tendency to come into bloom in September and later. Sometimes a tree would put out quite a sprinkling of bloom.

The question of concentration of nitrates has also been suggested. I had this question in mind when, in Bulletin 155, I referred to the popular idea that the irrigating waters bring the "black alkali" to the surface, and discussed the fact that some seepage waters issuing from certain shale banks contain significant quantities of nitrates. It was then shown that the shales contained no more nitrates than could be readily accounted for by assuming their origin to be in the soils of the mesas above them, which assumption is suggested by the occurrence of areas which are very rich in nitrates on various parts of these mesas. Case 19 in which we find a very considerable number of such occurrences stretched along for a distance of probably five miles, is one in point. This area lies above and extends southward from the point where the shale sample showing 0.03 percent of nitrates was taken. The intensity of the fixition or fixation and nitrification which has taken place in this area is indicated by the analyses given in connection with this case. While many of these occurrences made their first appearance in 1909 and 1910, over 2.0 percent of nitrates was found in an alkali collected on this mesa in 1907 and the aqueous extract of a soil sample taken the same year, 1907, contained nitric acid equivalent to 6.00 percent of sodic nitrate calculated on water-soluble or nearly 0.40 percent calculated on the air-dried sample. It is evident that leaching from the shales cannot possibly account for the occurrence of nitrates in the soils many feet above them. A similar argument applies to all of the geological formations occurring within the affected territory, i. e., they are wholly inadequate to account for the observed occurrences which are found above as well as below the various strata which might be taken as illustrations; in other words, the occurrences are wholly independent of the geological formations.

It may be further mentioned that no other occurrences of nitrates have been found either in excavations, borings or elsewhere which might be considered the source of any of the nitrates. Again, as previously urged, the general distribution of these nitrate patches requires for its explanation the existence of some very widely distributed source or generally occurring cause.

The fact that these nitrate spots are generally associated with wet land has led to the idea that the ground and even ditch waters may be accountable for them and consequently that drainage will obviate the trouble. It would in some cases be of decided benefit to drain the lands, and might possibly change the location of the nitre area by changing the area in which the condition of optimum

moisture prevails, but my observations lead me to have little hope for immediate and satisfactory results from drainage. In Case No. 8 I gave the conditions of the ground and those of adjacent lands in some detail for the purpose of showing that these adjacent lands do not furnish the nitrates and that the ground water would not, even if it flowed into this land, Case No. 8, account for the presence of any nitrates as they are not present in this ground water, nor yet are they, the nitrates, contained in the white, ordinary alkali of the surrounding lands which is essentially a mixture of sulfate and chlorid of sodium.

In regard to drainage, Cases Nos. 8 and 9, light clayey to sandy loam soils, with sandier subsoil underlaid by gravel, located on the river bank and from 12 to 15 feet higher than the river bed present ideal drainage conditions, and yet these cases presented, in 1909 and 1910, extreme instances of very high degrees of concentration of nitrates with most disastrous results, so far as the orchards and crops were concerned.

The ground water from the adjacent land but also the drain water from an adjoining similar soil showed actually less nitrates than is often present in good drinking waters, yet there is a very rich nitre patch near the river bank east of this drain. We have in this connection conclusively shown that such drain water cannot be the source of the nitrate. It is easy to suggest various explanations and remedial measures as applied to individual cases, especially if they are simply suggested explanations without regard to a wider range of facts, or suggested remedies never to be taken seriously as the basis of acts. The facts in such cases as have just been cited do not support these suggestions nor commend these remedies. Drainage, for instance, so far is I know, has given in these cases mostly disappointing results. Cases Nos. 8, 13, 15, 24 and 25 can all be interpreted in this sense. Apropos to this point I may mention the statement of a field agriculturist in answer to my question relative to the general results obtained by drainage; his answer was that they were generally more or less disappointing. We have cited two instances, Nos. 8 and 9, in which nature has made a perfect application of this remedy and it proved wholly inadequate to ward off or to mitigate the evil. I know of no more intense instance of this trouble than is presented in Case No. 9, while Case No. 8 is very bad. In the latter case the successive owners have combated the trouble persistently for about seven years. They have tried the application of extremely large quantities of manure, frequent and thorough cultivation, also frequent and excessive irrigation in the endeavor to wash out what they thought to be black alkali. Prior to 1904 there was no trouble with this portion of the field; it was as good and as productive as the rest of the land, but from that time on it has been

bad and has slowly grown worse during the time that I have had it under observation.

It may be wise to state that it is not intended that any one should infer that I doubt the value of drainage in removing excessive water from land, but simply to state that at the present time I do not believe that we have much reason to hope for any material relief from this trouble by drainage, even in cases of comparatively low lands, while it is wholly out of the question in cases of high or naturally well drained lands. If these lands could be kept covered with water to a depth of several inches, twelve or more, for a number of days and then be thoroughly drained out the aerobic bacteria might in this way be killed off and the excess of nitrates removed; but this could be applied to small and favorably located areas only; the costs would be heavy and the permanency of any benefit doubtful. This, however, has not yet been tried.

Cases Nos. 8 and 24 of this bulletin and No. 3 of Bulletin 155 present the facts relative to what we may hope from flooding or persistent washing of the soil more fully than any others that have come under my observation. Case No. 8 is particularly instructive because the drainage is apparently perfect and it received twelve profuse irrigations in the season of 1909, and yet in 1910 the puffed and mealy condition of the soil was as bad as I had ever seen it and the surface soil was very rich in nitrates. The effort made in 1909 to wash out this soil was apparently futile, and we have shown by analyses of the soil, of alkali and of the ground water from adjacent lands that these nitrates do not come from these sources and the nitrates found in 1910 do not represent a resupply from this source. There is no question but that these nitrates can be temporarily washed out of the soil, but they were as abundant, if not more so, in 1910 than they were in 1909 when the land was irrigated twelve times in the endeavor to wash out the "black alkali." I have presented in Case No. 24 an analysis of a sample taken in June which, as I take it, represents the salts present in the surface soil under ordinary conditions; also of a second sample taken in September, because this ground was flooded twice in the month of August, once to a depth of two feet which required 24 hours to flow or drain off. The easy solubility of the nitrates makes it a matter of surprise that we should find about a month subsequent to the last flooding not only so large an amount of soluble salts but also so large a quantity of nitrates present. Case No. 3 was given in Bulletin 155; in this case the owner had tried for 16 years to bring these spots under subjection; he had plowed and flooded, but without success. I have not as yet seen or learned of any result obtained by flooding which gives any solid basis for expecting very permanent, beneficial re-

sults from this operation. Perhaps frequent and repeated flooding combined with drainage, where needed, might prove effective.

If the nitrates are not present in the various geological strata and there are no local deposits scattered all over large sections of the state in which we may find the source of these nitrates occurring in our soils, the question, Whence do they come? is germane.

The facts stated in connection with Case No. 8 are, I believe, perfectly applicable to all other cases and it can be stated, without any material modification, that these nitrates are not the product of concentration of ground waters flowing from other lands as they, these ground waters, contain no nitrates; neither did the soil, examined to a depth of three feet, nor the white or common alkali which was abundant on this adjacent land contain any nitrates in 1907. Further, they are not due to the concentration of surface washings.

There is one remote possibility, which so far as I know, has not been suggested, i. e., the water used for irrigation. While this is an extremely remote possibility, we can answer the suggested question. We have sanitary analyses of several of the river waters, also of reservoir waters, which are used for the purposes of irrigation, and the nitrogen present as nitrates varies from a trace to 0.400 part per million, a quantity not only too insignificant to be considered a factor in the problem, but so nearly zero that it shows that there are no nitrates in the rocks of the drainage areas of these rivers to which the nitrates may be traced.

The answer that I suggested in Bulletin 155 was that these nitrates are formed where we find them. That the nitrogen is taken from the atmosphere by azotobacter and is subsequently changed into nitric acid, respectively nitrates, either by the azotobacter themselves or by other bacteria. So far in this bulletin I have presented facts in abundance to establish the occurrence of very large quantities of nitrates in certain of our soils, and that the concentration in hundreds—I am fully justified in saying thousands—of instances, is most remarkable, but all proof adduced bearing upon their origin has been by a process of exclusion, i. e., the nitrates are present but they have come from nowhere, therefore they are formed in *situ*.

In Bulletin 155 I showed by nearly 300 nitrate determinations that many of our soils contained very notable quantities of this substance. At the time these determinations were made, October, 1909, we found this quantity varying from 12 to 1,920 pounds per acre in the top six inches of soil, calculated as sodic nitrate. These samples were from cultivated fields in good condition which had been planted to beets. The highest results were obtained in the turn rows.

I have been unable to find any more satisfactory data relative to the amount of nitric nitrogen in soils than was given in Bulletin 155, page 37, based upon Rothamsted results which showed that in lands cultivated as bare fallow about 80 pounds of nitrogen were converted into nitrates in 14 or 15 months. This includes the nitric nitrogen removed in the drain waters. If this amount were all present at one time and contained in the surface foot of soil it would amount to only 0.002 of one percent. In the top 18 inches of another field they found in September and October 49 pounds of nitric nitrogen. If this were all contained in the surface foot at a given time it would correspond to 0.001225 percent. The statement is made that this large amount is due to the richness of the soil in nitrifiable matter, showing that 49 pounds per acre to a depth of 18 inches was considered high, if not unusual. The ratio of the nitric nitrogen to the total nitrogen at any time is not given. It is well known that the nitric nitrogen present in soils varies from time to time owing to several causes, but the easy solubility of the nitrates makes it very probable that the amount of them in the surface soil will be dependent upon the amount of rainfall and the time which has elapsed between the last rainfall and the taking of the sample. The character of the soil, i. e., the readiness with which it allows water to pass through it, its power to retain the nitrates, and the evaporation which takes place from its surface will also influence the amount of nitric nitrogen present at a given time. Rainfall does not usually play the important part with us that it does in England or in the eastern states; if it ever does, it is only for short periods of time.

The samples of soils used for the determination of nitric nitrogen in Bulletin 155, pp. 38 and 39, were taken at the close of a wet season, that is, for Colorado. We had had 3.36 inches of rainfall between September 12 and December 1, and .47 inches during the month of December, and yet we found a maximum of 320 pounds of nitric nitrogen in a set of 46 samples taken between October 1 and 15. The samples were taken to a depth of six inches. In another set of 54 samples taken January 26-31, we found a maximum of 280 pounds of nitric nitrogen in the top six inches of soil. It is to be remembered that these samples were from fields which had been planted to beets. The last sample was taken from the turn row. These quantities are so materially higher than those given for Rothamsted soils, though these Rothamsted fields had been cultivated as bare fallow, that we can scarcely compare them at all. In the case of the 80 pounds of nitric nitrogen per acre in the Rothamsted soils the nitric nitrogen removed by drainage has been determined and included. In these Colorado samples only the nitric nitrogen which was present in the soil to the depth of six

inches at the time the samples were taken is considered—drainage or greater depths are not considered.

I have the record of a considerable number of analyses of our Colorado soils and they scarcely average over one-tenth of one percent total nitrogen which, judged by ordinary standards, cannot be said to be more than a fair supply of nitrogen.

The prairie soils of Illinois, as given in their Bulletin 123, contain from two to four times as much, and even their subsoils contain more nitrogen than our surface soils. The soils of Kentucky, Bull. 126, are likewise much richer in total nitrogen than ours. Storer, Vol. II p. 76, says that Krocker, and Payen also states that cultivated land seldom contains less than 0.10 percent of nitrogen and that they usually contain a much larger quantity. He states further that A. Mueller found, on an average, 0.26 percent of nitrogen in the surface soils poor in lime and 0.15 percent in their subsoils. In the surface soils of limestone regions he found, on an average, 0.66 of nitrogen.

King states that the mean amount in eleven arable soils at Rothamsted is placed by Lawes and Gilbert at 0.149 and for eight others at 0.166 percent. Four Illinois prairie soils were shown by Voelcker to contain 0.308 percent; seven Russian soils according to C. Schmidt contained 0.341 percent. The average of these thirty is 0.219 percent. Lawes and Gilbert gave four Manitoba soils as containing 0.373 percent of nitrogen. Hilgard states that from 0.1 to 0.2 percent of total nitrogen in non-acid soils is considered adequate.

Our Colorado soils are non-acid soils. I have as yet, found but one case of an acid soil, not considering beds of peat. In seventy-three analyses of Colorado soils taken in various parts of the state twenty-two of them contain less than 0.1 percent total nitrogen and fourteen contain 0.2 percent or more, leaving thirty-seven or a little over a half of the samples considered which contained 0.1 percent and more, but less than 0.2 percent. It is only a few weeks since, that an analysis of a Colorado soil was submitted to me for my interpretation. The reason for this was that parties in Illinois having the purchase of a tract of Colorado land under consideration had a sample of the soil analyzed and as it contained only 0.08 percent of nitrogen or a trifle less, they, I understood, declined to buy it.

Other soils from sections of this state have, according to reports, been found to be deficient in nitrogen and yet these soils produce excellent crops of corn and wheat. According to our analytical data there can be no question but that many of our soils, according to the standards adopted, are low in nitrogen but they produce excellent crops, in favorable seasons, 60 and even 80 bushels of wheat to the acre, while from 35 to 50 bushels per acre

are common yields. The standards adopted and our analytical data are not in perfect harmony with the common facts of actual practice. This has been observed by others and is not new. Trained and practical agricultural chemists who have had years of experience in this state, have stated to me that they had not observed any indication that our crops ever suffer from the lack of nitrogen, and they were perfectly well aware of the fact that according to analytical results many of our lands are deficient, or at best only moderately well supplied with this element.

In regard to the ratio of nitric nitrogen to the total nitrogen in soils the statement that it, the nitric nitrogen, seldom amounts to 5 percent of the total is attributed to Warington. This may be taken as a maximum. There is recorded in Bulletin 126 of the Kentucky Experiment Station, 24 analyses of soils in which both the total and the nitric nitrogen have been determined, which show that the nitric nitrogen varies from 0.0 to 1.263 percent of the total nitrogen present. The total nitrogen in the sample showing the largest amount of nitric nitrogen was 0.238 percent of the soil. The land from which this soil sample was taken had been set to tobacco which had failed. The authors, A. M. Peter and S. D. Averitt make the statement: "The effect of the large amount of nitrate was evident in the better growth of the wheat where the tobacco failed." In another case in which the nitric nitrogen amounted to 0.826 percent of the total nitrogen the authors make a similar statement. "The larger proportion of nitrate where the tobacco was poor is to be noted here, as before, and the effect of this upon the wheat was very apparent." The authors consider these quantities of nitric nitrogen as large and apparently as injurious enough to account for the bad condition of the tobacco. In our Laboratory No. 697 we find the total nitrogen equal to 0.080 percent of the soil, which is probably a little too low, while the nitric nitrogen in the same sample equalled 0.0377 percent of the soil or 47.07 percent of the total nitrogen. This was a sample taken to a depth of twelve inches. It is a very bad soil but not nearly so rich as some samples with which we have met, especially in the cases of surface samples. In Case No. 6 the surface foot of soil, which proved to be an exceptional one, as it was poorer in nitric nitrogen than the second foot, the nitric nitrogen constituted 1.86 percent, in the second foot 1.9 percent and in the third foot 55.3 percent. This is almost the only instance in which we find more nitric nitrogen in the deeper samples than in the shallower ones. The surface soil is not included in the sample designated as the first foot. The nitric nitrogen in the surface portions of this soil, taken perhaps thirty feet north of where these soil samples were taken, amounts to 0.053 percent of the air-dried soil or 530 parts per million. The total nitrogen in this surface sample was

not determined. Judging from results in other samples, the nitrogen was probably almost wholly present as nitric nitrogen. In a series of 54 soil samples taken to a depth of six inches the minimum of nitric nitrogen equalled 1.5 percent while the maximum, debarring an execptionally high one, was 17.1 percent of the total nitrogen. I have already cited an instance in which the nitric nitrogen in the third foot of soil was equal to 55.3 percent of the total nitrogen, this, however, was an exceptional sample, not in the amount of nitric nitrogen present but in the location of the nitric acid in the soil.

The nitric nitrogen in other, mostly surface samples, ranges from 16 to 93 percent of the total nitrogen. The latter percentage, 93, seems extremely high but the total nitrogen was determined in duplicate and the determination of the nitric nitrogen was also made in duplicate by different parties, using slightly different methods of preparing the material for the determination of the nitric acid. The agreegent between these determinations was entirel ysatisfactory. The difference falling in the third decimal place. Two samples, our No. 1054 and 1055, illustrate the great variation in the amount of nitric nitrogen in affected and unaffected soils. No. 1054 is a sample of surface soil taken to a depth of four inches near to a recently killed tree, while No. 1055 is also a sample of surface soil taken from supposedly unaffected ground 600 to 800 feet north of the former and just outside of the orchard. No. 1054 contained 0.0932 percent total nitrogen and 0.0150 percent nitric nitrogen, or 16.09 percent of the total; No. 1055 contained 0.0844 percent total and 0.0003 percent nitric nitrogen or 0.355 percent of the total. The soil conditions were entirely different in these two cases though they were relatively close together.

Fixation—In Bulletin 155 I presented the fact, ascertained by Professor Sackett, that the aqueous infusion of some of our soils induced a very marked fixation of nitrogen, the maximum given at that time being 13.02930 milligrams in 20 days for each 100 c. c. of mannite solution. The questions pertaining to the relation of the azotobacter to fixation and nitrification may be worked out in detail by Professor Sackett, but I have endeavored to determine the practical facts on a large enough scale to be conclusive so far as these processes in our soil are concerned. For this purpose I took five portions of soil of 1,250 grams each. The moisture content was determined at 100° and boiled, distilled water added to make the total water equal to eighteen percent of the moist soil. The weight of the dish and soil was determined and noted in order to be able from time to time to add water enough to replace loss due to evaporation. At the same time

samples of the soil were brought to a thoroughly air-dried condition and the total, and also the nitric nitrogen determined. Four of the large dishes with their charges of soil were placed in an incubator and were kept at a temperature of about 29° C. for 27 days, when a sample was removed from each dish for examination. The fifth dish was covered and placed in an unused room.

Two of the four dishes placed in the incubator were inoculated by the addition of 25 grams of another soil in which the total and nitric nitrogen was determined, because a culture test made from the sample of soil taken for this experiment gave unsatisfactory results, as no proper membrane was formed, only a few gelatinous masses at the edge of the culture medium. I feared that I would have to collect other samples of soil and repeat the experiment, as I had already had to do once, for the first sample of soil that I gathered for this purpose, though it was very rich in nitrates, seemed to contain no living bacteria which Professor Sackett, on whose judgment I relied, was willing to accept unqualifiedly as virile azotobacter. This precaution, however, proved to be unnecessary, for a sample of soil taken from the fifth dish, on the thirteenth day of the experiment, gave a very heavy membrane in four days. The soil in this dish had already begun to show a change of color on its surface at the time this sample was taken. The membrane in the culture flask began to show brown points by the eight or ninth day. This fifth dish had been kept in a south room where for part of the day it received the sunshine, modified by a screen of paraffined paper. We have five dishes, each containing originally 1,250 grams of soil with eighteen percent of moisture. On the twenty-seventh day I removed from each dish 170 grams of the moist earth, brought it to a thoroughly air-dried condition and made nitrogen determinations in triplicate on each sample. I have mentioned five samples, but I added another, i. e., a sample of the original soil which had been put into a show bottle while moist and allowed to stand in the room. If moisture, air and an equitable temperature be the requirements for the fixation of nitrogen I could see no reason why I should not expect an increase in this sample as well as in those placed in the incubator, perhaps not so great an increase, but still an increase. Samples A, B. C and D were put into the incubator, sample E was moistened and kept at the room temperature and F was the original sample in its moist condition.

The original soil, thoroughly air-dried, gave 0.105875, 0.11000 and 0.105875 percent of nitrogen, average for total nitrogen 0.10725 and 0. 0035 percent of nitrogen as nitrates, equal to 3.263 percent of the total.

	Percent total nitrogen at the end of 27 days.		Milligrams gained per 100 grams soil in 27 days.
Sample A gave	0.11688 0.11688 0.11963	Average 0.11779	10.54
Sample B gave	0.11550 0.11688 0.11825	Average 0.11688	9.63
Sample C gave	0.11413 0.11413 0.11413	Average 0.11413	6.88
Sample D gave	0.11550 0.11413 0.11550	Average 0.11504	7.79
Sample E gave	0.11275 0.11275 0.11413	Average 0.11321	5.99
Sample F gave	0.11275 0.11130 Lost	Average 0.11207	4.82

The fixation obtained and given in Bulletin 155, p. 46, is given for each 100 c. c. of the culture medium. In order to make the figures easily comparable we have given these results in milligrams per 100 grams of soil. The soil experimented with was simply a good, arable soil collected from the College farm at or near a point where I had observed the development of brown patches. It is not one of the soils in which we have observed excessive quantities of nitrates but even here the nitric nitrogen amounts to 3.27 percent of the total. The quantities fixed in 20 and 30 days in a mannite solution inoculated with an infusion of 10 grams of soil are exhibited in the following table along with the fixation accomplished in these samples of soil in 27 days. The inoculation of the two samples seems to have made no difference whatsoever.

NITROGEN FIXED

	Milligrams in 100 cc. in 20 days	Mannite-Solution in 30 days	Sample	In 100 grams of soil in 27 days
Sample 1.	0.00000	1.05075	A	10.54000
Sample 2.	1.19085	0.56040	B	9.63000
Sample 3.	3.08220	3.43245	C	6.88000
Sample 4.	6.16440	12.46890	D	7.79000
Sample 5.	0.84060	3.08220	E	5.99000
Sample 6.	0.77055	3.57265	F	4.82000
Sample 7.	3.50250	3.01215		
Sample 8.	2.38170	2.87205		
Sample 9.	13.02930	10.15725		

All of the ordinary analytical precautions were taken and the nitrogen obtained in the blank test, also run in triplicate, has been deducted. Each of the seventeen separate determinations made on these six samples show a decided increase in the amount

of nitrogen. In this climate I find that the thoroughly air-dried material presents almost as good a basis for comparison as is possible for us to get, which would not be the case in a humid atmosphere.

When we consider the nitrification we find equally interesting results. As already stated, this sample of soil contained at the beginning of the experiment 0.0035 percent of nitrogen as nitrates, on the twenty-seventh day of the experiment the various samples gave the following:

NITRIC NITROGEN IN SOIL SAMPLES INCUBATED FOR TWENTY-SEVEN DAYS.

	Percent in Soil		Percent of Gain
Sample A.	3/3	0.0055	54.29
Sample B.	3/3	0.0057	62.85
Sample C.	3/3	0.0060	71.43
Sample D.	3/3	0.0065	85.71
Sample E.	3/3	0.0036	———
Sample F.	3/3	0.0043	22.85

These results show clearly that both fixation and nitrification took place in all of the samples except E, in which nitrification is insignificant or zero, while the fixation amounted to 5.99 milligrams per 100 grams of soil. At one time one of the dishes in the incubator smelled distinctly of butyric acid, but this odor disappeared within a few days and all of the dishes had the pleasant odor of fresh soil when the samples were taken out of the dishes.

The remaining portions of the samples, after having been thoroughly wetted with boiled, distilled water were returned to their original positions and only a little more water, not weighed, added till the forty-eighth day when this series of experiments was terminated. Four of the dishes were replaced in the incubator. One dish was covered and placed at the bottom, the other three dishes were not covered as in the first period except as each succeeding one served as a cover for the one next below it. The top one of course was without any cover. Two beakers, containing water, were also placed in the incubator to aid in saturating the atmosphere with moisture and to lessen the evaporation from the soil. The moisture in the samples on the forty-eighth day was determined and found to be for A, 13.5, for B, 14.5, for C, 17.0, and for D, 20.0 percent. These are the four dishes placed in the incubator. Sample E, which was kept in a covered dish at the temperature of the room, contained 17.5 percent of water. The moisture in sample F, which was the original soil kept in a show-bottle, was not determined.

		Percent of total nitrogen in soil at the end of 48 days.		Milligrams nitrogen gained by 100 grams soil in 48 days
A	1	0.12276		
	2	0.12144	Average 0.11968	12.43
	3	0.11484		
B	1	0.11484		
	2	0.11748	Average 0.11748	10.18
	3	0.12012		
C	1	0.11616		
	2	0.11880	Average 0.11792	10.60
	3	0.11880		
D	1	0.11484		
	2	0.11748	Average 0.11660	9.30
	3	0.11748		
E	1	0.11616		
	2	0.11880	Average 0.11924	12.00
	3	0.12276		
F	1	0.11484		
	2	0.11356	Average 0.11529	7.99
	3	0.11748		

Sample E, which contained 17.5 percent of water at the end of the experiment and had received direct sunlight every day, developed quite a growth of algae, showing on the surface as green and brown spots. These proved to be, for the most part, oscillaria and diatoms, which became very evident in a culture of these made on sand. The incubator samples of course showed no growth of this sort, but sample A made even a larger gain in total nitrogen and the same gain in nitric nitrogen as sample E on which the algae grew. So it is not clear whether the algae exercised any influence upon the result or not. The gain in both total and nitric nitrogen was, however, much more marked in sample E during the second period of the experiment than in any other sample during this period. The order of the samples in regard to gain during the second period is E, C, F, A, D, B, but in no case had reverse changes set in to such an extent as to wholly conceal the increase. It is, perhaps, unfortunate that I did not extend the examination of the soil to include the ammoniacal and nitrous nitrogen at the beginning and end of the experiment as well as the total and nitric nitrogen.

Returning to the increase of total nitrogen in the soil it may be well to state it in terms of perecntage, calculated on the amount of nitrogen originally present. Such a statement gives us for A, 11.589; E, 11.188; C, 9.883; B, 9.492; D, 8.671 and for F, 7.449 percent. The maximum gain calculated on the amount of nitrogen present at the beginning of the experiment is 11,589; the minimum 7.49 and the average for the six samples is 9.712 percent.

The gain of the total nitrogen in the case of sample F, is worthy of special note. This sample was the original just as it

was gathered and put into a round bottomed bottle loosely closed with pieces of paste board and allowed to stand in the room where the sun shone on it part of the day. In this case we find a gain of 7.99 milligrams for each 100 grams of soil in 48 days, equal to 7.449 percent of the nitrogen originally present. In this connection an observation made in 1900 is interesting. The observation is noted in Bulletin 65, p. 45, and raises this question of the increase of nitrogen in samples kept in the laboratory for some time, in the case mentioned, fifteen months, though air-dried, bottled and corked but not sealed. We found a gain of twenty-eight pounds of nitrogen per acre-foot, too small to be conclusive.

Nitrification—The original sample contained nitric nitrogen at the beginning of the experiment equal to 0.0035 percent, and at the end of forty-eight days, the samples contained the following amounts:

		Percent nitric nitrogen in soil at end of 48 days.		Gain in percentage of nitric nitrogen originally present in 48 days.
A	1	0.0060		
	2	0.0060	Average 0.00600	71.43
	3	0.0060		
B	1	0.0060		
	2	0.0060	Average 0.00587	67.71
	3	0.0056		
C	1	0.0080		
	2	0.0070	Average 0.00750	114.24
	3	Lost		
D	1	0.0080		
	2	0.0090	Average 0.00833	138.00
	3	0.0080		
E	1	0.0060		
	2	0.0060	Average 0.00600	71.43
	3	0.0060		
F	1	0.0040		
	2	0.0040	Average 0.00417	19.15
	3	0.0045		

These tables show beyond a question that both fixation and nitrification have taken place, the former in far greater degree in absolute, but the latter in an even more marked degree in relative measures. In two samples the nitric nitrogen has much more than doubled.

All of these samples except F had become decidedly darker on the surface than they were at the beginning.

We have in these samples the reproduction of the main features presented in our fields, the production of nitrates, the fixation of nitrogen and the browning of the surface soil. The water content of the samples was chosen at about 18.0 percent because my observations in the field have led me to the conclusion that the

optimum amount is probably below rather than materially above this percentage. The determination of the optimum amount of moisture under specific and varied conditions would be interesting but is a detail not included in the general features which I am endeavoring to present. We have the maximum nitrification in the sample containing 20 percent of water at the end of the experiment. My judgment is that this amount had scarcely varied at all during the experiment. On the other hand we have the maximum fixation in the two samples containing 13.5 and 17.5 percent respectively. These results may be accidental but they agree well with my observations in the field. The amount of fixation, however, is quite uniform and the addition of water, at least up to 17.5 percent has clearly promoted it.

The chemical composition of this soil is fairly represented by our Laboratory Nos. 724 and 725, representing the soil and subsoil from a portion of this same tract. These analyses were given in Bulletin 155, p. 36.

ANALYSES	XCII Soil Laboratory No. 724 Percent	XCIII Subsoil Laboratory No. 725 Percent
Insoluble	54.653	57.068
Silicic acid	19.805	12.754
Sulfuric acid	0.047	0.049
Chlorin	0.032	0.059
Phosphoric acid	0.120	0.127
Carbonic acid	3.048	6.312
Lime	6.100	8.465
Magnesia	1.355	1.448
Sodic oxid	0.290	0.432
Potassic oxid	0.872	0.742
Ferric oxid	5.601	3.499
Aluminic oxid	3.738	5.397
Manganic oxid	0.118	0.026
Ignition	5.072	3.887
Sum	100.851	100.265
Oxygen equiv. to chlorin	0.007	0.013
Total	100.844	100.252
Total nitrogen	0.147	0.069
Humus	0.426	

While these analyses are not made on the soil actually used they serve to represent its composition as well as a sample taken in any fair-sized field may represent its soil.

The amount of nitrogen fixed is very large and seems incredible. Taking 10.54 milligrams as the quantity fixed in 100 grams of soil in twenty-seven days and calculating the amount that would be fixed in the top two inches of the soil per acre, we have 937 pounds, or for an acre-foot 5,622 pounds, equivalent to about 17.5 tons of proteids (N x 6.25) per acre-foot, a quantity which seems extremely large, but this is the result actually obtained.

The maximum gain in nitric nitrogen calculated per acre-foot per annum corresponds to five tons of sodic nitrate.

Perhaps emphasis should be laid on the fact that these soil samples experimented with were, as stated, samples of an ordinary soil collected from the College farm at or near a point where I had observed the brown color which serves me as a guide and which I suggested was probably due to the brown azotobacter pigments. Further, that nothing was added to the sample except distilled water which had been boiled to expel any trace of ammonia that it might contain.

However puzzling the facts may be they are simple; the nitrates are present in large quantities in areas scattered over 300 to 400 square miles as a conservative esitmate. These occurrences of nitrates are independent of geological horizons and do not owe their origin to the neighboring or surrounding country. Nitrates occur in some lands surrounded by others in which nitrates do not occur. They are not present in the alkalis or the ground waters occurring in these surrounding lands; again, they occur on elevated mesas at such heights and under such conditions of location, that they could not be accounted for in this way, i. e., as concentrations from other lands. On the other hand we have shown that both fixation and nitrification take place in our soils, in a notable degree, and we have every reason to believe, because of the observed intense local developments, that our results, obtained with the samples of soil from Fort Collins, are much less intense than those actually produced in many localities. I know that there are questions unanswered, but it seems to me that it makes little difference to the facts, whether we know whence comes the energy which is assumed to be the *sine qua non* for the development of azotobacter or not, the fact is, they do develop. In our case a culture test at the beginning of our experiment gave unsatisfactory, but not absolutely negative results; another sample taken from one of the dishes, not inoculated, after a period of 13 days gave in four days a very strong membrane. The two samples were in no way comparable in their development. There were positive indications on the surface of the soil in the dish that it was becoming brown before we took the second sample. The rapid and profuse growth of azotobacter in the culture medium indicated either a very greatly increased abundance of the bacteria themselves or an immensely increased virility. The question of whether the azotobacter both fix the atmospheric nitrogen and convert it into nitric acid, respectively nitrates, or whether this latter work is done wholly by another genus or other genera of bacteria is, perhaps, a question to be settled—but, be it settled as it may, our facts remain the same that we have instances of the accumulation of very large quantities of nitrates in our soils always associated with the brown color which

we know to be caused by the azotobacter. I believe, and this belief is based upon tentative facts, that the azotobacter are at the same time nitrifiers, i. e., that the possess a double function which I believe has already been asserted but not generally accepted. I will state that Professor Sackett is not in any way responsible for this view and I do not know his attitude on this specific subject. These matters of theory and function are open ones but the fact of fixation of nitrogen and the formation of nitrates in our soils to such an extent as to kill fruit trees and ruin the land are established ones.

I expect to present another bulletin in the immediate future dealing with another phase of the subject, i. e., the general effects of the nitrates upon the sugar beet, which will also continue these soil questions.

SUMMARY

The problems presented involve the occurrence of nitrates in such unusual quantities, that I may say, I hope without offence, that even the oldest and most experienced men have not seen the equal of it and have no conception of the facts.

These nitrates occur so abundantly on very many square miles of otherwise good land as to be either prejudicial or fatal to vegetation.

The apple tree has practically been adopted in this and preceding bulletins as the criterion whereby to judge of the intensity and extent of the injurious effects of the nitrates, though other trees and crops, especially the sugar beet, have been mentioned.

The damage done to apple orchards in this state is very serious. If we should estimate the trees killed within the past two years as equivalent to six hundred acres of orchard I believe that it would be a conservative estimate.

These injurious effects of nitrates in cultivated soils are so new and so extensive that we cannot wonder that the layman or even the scientific man who has not seen them, fails to grasp them as facts or if they do and realize their importance, that they hesitate to acknowledge it.

The trees all die in the same manner. This applies to the apple, pear, peach, apricot, willow, elm, cottonwood and other poplars, and to vegetation in general.

Experiments were made with sodic nitrate by applying it to apple trees, when it produced the same effects on the leaves and killed the trees in the same manner as these orchard and shade trees are observed to die.

This series of experiments, eight of them, was not repeated because the results were concordant and conclusive. Experiments were also made using sodic chlorid, common salt, in sufficient quantities to injure the foliage. The effects were unlike and easily distinguished from those produced by sodic nitrate.

The manner of attack, the effect produced and the very rapid termination of the trouble in the death of the trees indicate the action of the same cause.

The identity of these effects with those produced by sodic nitrate, and the presence of very unusual quantities of nitrates in all of the soils where this trouble is met with are accepted as conclusive proof that the nitrates are the cause of it.

No attempt has been made to determine the limit of tolerance of the apple tree or other plants for nitrates. It has, however, been observed that an established beet plant can endure immense quantities of them, but not without deterioration in quality.

The problems presented are not those of ordinary alkali, nor of seepage, nor yet of the occurrence of nitrates produced in the soil by

nitrification as generally understood, but their occurrence in unusual, detrimental and fatal quantities, over areas measured by the square mile of territory.

The nitre question presents a distinct problem whose relation to the problems of alkali, seepage and drainage is not so intimate as is indicated by the statements made in Bulletin 155.

The statements of Bulletins 155 and 160 in regard to the cause of the "brown spots," the character of the salts present, their fatal effects upon vegetation and their extremely deleterious action upon the soil are corroborated.

The spread of the trouble during the year 1910 was very marked.

The intensity of the attacks has increased rather than abated.

Some instances of a very rapid development combined with extremely intense action have been observed. In one fourteen-year-old orchard not less than twelve acres of trees, apple, plum, pear and cherry, together with currant bushes and other small fruit have been killed in less than a year. The water table in this land was not, at any time, near enough to the surface to do any damage.

No single instance of the death or eradication of a brown area, a nitre spot, has been observed; but the interior of such areas has been found so excessively rich in salts that the ground has become barren, even of the azotobacter flora.

This deportment of the bacteria suggests the probability that the land may again become fertile after a few years, in fact, varieties of Atriplex, saltbushes, are already taking possession of land which has been devoid of vegetation for several years.

The drainage in several of the cases given is excellent, in other cases drains have been laid for periods of from one to five years without preventing the formation of nitre areas.

Trees badly affected by this trouble show almost no recuperative power, probably due to the continued excessive supply of nitrates in the soil, possibly to the severe toxic action of the nitrates. So afr as our observation goes both factors seem to be involved. Slightly affected trees may recover but no badly affected tree has been observed to do so.

The generally observed change in the soil, indicating danger to the trees, is a turning brown of the surface which is expressed by the statement that "The soil turned brown or black and the trees died."

The samples of brown soil have, without exception, contained excessive quantities of nitrates.

The color is not due to the nitrates nor to sodic carbonate or black alkali proper but to the development of pigments by the azotobacter. This applies to the soils here described. Some soils may have a brown color due to other causes.

This condition is usually preceded and accompanied by a mealiness of the soil, often described as ashy. There is usually but little or no efflorescence on such soils, though it sometimes occurs.

The time required for the killing of a tree varies with the virulence of the attack, in bad cases from four days to two weeks. Slightly affected trees may linger a long time.

These areas may occur in perfectly drained land, situated in the midst of land which shows no abnormal quantities of nitrates.

In one case, and possibly in others also, injury to many trees followed the application of water, probably due to the washing of the nitrates down into the soil.

The river waters used for irrigation, whether stored or not, contain no unusual quantities of nitrates.

The ordinary white alkali that commonly occurs in these sections is, for the most part, free from nitrates, but the brown and white areas frequently overlap.

The ground waters, unless derived from nitre areas, are free from nitrates and these nitrates cannot be accounted for by the evaporation of such water from the surface of these areas.

In some sections practically the whole of the irrigated land has been affected, thus eliminating the question of transportation except as to the river water used for irrigation. Our river waters carry from 0.00 to 0.4 part per million of nitrogen as nitrates.

The localization of these areas and the rate of increase also preclude the theory of transportation and concentration.

Excessive irrigation for the purpose of washing out the "black alkali," nitrates, has not been successful, but this failure has probably been due to the method used.

The liberal application of manure has not given permanent, if indeed, any relief.

Thorough and frequent cultivation has not been followed by the beneficial results expected.

The soils of Colorado are, generally speaking, poor in nitrogen, but the ratio of nitric nitrogen to the total nitrogen is frequently very high, 17 to 50 percent being not uncommon.

The nitrogen in these soils is fixed by azotobacter which use the nitrogen in the air to build up their tissues.

The fixation of nitrogen, in a sample of ordinary soil from the College farm, collected December 12, 1910, on incubation for twenty-seven days, was found to have taken place at the rate of 5,222 pounds of nitrogen, equal to 17.5 tons of proteids per acre-foot of soil per annum.

The nitric nitrogen present in this soil at the beginning of the experiment corresponded to 840 pounds of sodic nitrate per acre-foot of soil; this had increased in 48 days to 1,999 pounds as a maximum, a gain of 1,159 pounds which would give, if this rate were continued for a year of three hundred and sixty days, a gain of 8,676 pounds, or four and a third tons of nitrates per acre-foot of soil.

The incubated samples, with but one exception, showed a darkening of their surfaces.

No addition of anything except boiled, distilled water was made to these samples before or during incubation. A large bottle was partially filled with some, approximately eight pounds, of the original sample just as it was collected. This bottle was loosely stoppered, inverted and kept in a room where the temperature was fairly high and even. This soil was analyzed just as the incubated samples were and showed a decided increase in both the total and nitric nitrogen, 7.45 and 19.15 percent respectively.

Fixation takes place rapidly in this soil in the presence of from 13.5 to 20 percent of water. The rate of fixation of nitrogen obtained is sufficient to account for the nitrates found in the soil provided that it is nitrified.

The rate of nitrification obtained is sufficient to account for the formation of the nitrates found, in most cases if not all of them.

The brown color of these soils is due to pigments produced by the azotobacter.

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BACTERIOLOGICAL STUDIES OF THE FIXATION OF NITROGEN IN CERTAIN COLORADO SOILS

BY

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BACTERIOLOGICAL STUDIES OF THE FIXATION OF NITROGEN IN CERTAIN COLORADO SOILS.

By Walter G. Sackett.

Somewhat over a year ago, Dr. Headden called my attention to the extremely large quantities of nitrates present in certain Colorado soils, stating at the time that these nitrates were frequently associated with a brown discoloration of the soil, and that this color was often confined to well defined areas varying in size from three feet in diameter to an acre or more; furthermore, that these so called "brown spots" were not fixed, inert quantities related to some recognized geological formation, but that they were alive, and in the process of making as evidenced not only by the rapid progress with which the then existing spots were spreading, but also by the almost continual appearance of new spots both in old and new localities.

Dr. Headden has been studying our alkali soils and drainage waters for the past sixteen years, and he tells me that complaints of "brown spots on which nothing will grow" have been common, but more so during the past five years; reports have been received from the cantaloupe growers that their melons are deteriorating in quality without any assignable cause; truck gardens, alfalfa, oat, barley and sugar beet fields have been developing barren patches where a uniform stand was always obtained in former years; in some parts of the state, the sugar content of the sugar beets as well as the purity and tonnage have fallen off until it is a ponderous question with the farmers and sugar factories whether the growing of sugar beets in those localities is any longer a profitable industry; but equally serious, if not even more so than any of these, is the destruction which is being wrought in some of the apple orchards of Colorado. Newly set trees, trees that have just come into bearing, and trees that are fifteen to twenty-five years old, in fact, trees of all ages, seem to suffer alike. It is not an isolated tree here and there that has died, but thousands, representing many acres of orchards in widely separated districts, have perished during the past two seasons.

When one is brought face to face with facts of such tremendous economic importance as these, he can scarcely fail to be impressed with the deplorable condition of affairs, and is forced to the position that something out of the ordinary is taking place, and that it is not without a cause.

With reference to the occurrence and distribution of the nitre areas, Dr. Headden gives the following in Bulletin 155 of this station:

"This trouble was not confined to any one section, but was common to several sections of the state. While it, in all probability, depends upon soil conditions, these conditions are met with in so many places that it is necessary to consider the condition rather than the soil

itself. It sometimes occurred in light and sandy loams, and sometimes in clayey soils. It is sometimes in comparatively low lying lands, again in the low lying portions of higher lands, and again on the hillsides. The road side, a ditch bank, and the cultivated fields represent the range of places in which this thing may reveal itself. There is one thing common in all of its occurrences, namely, a brown color in the surface soil. This color is less marked in the sandy soils than in the so-called adobe soils. Perhaps this is due to the presence of the deliquescent salts on the surface of the adobe soils, or more probably to the color of azotobacter films."

Fig. 1. Nitre area in an orchard showing the characteristic dark spots. Sample No. 30.

"We find the nitrates present in soils, where there is a great deal of moisture, but in places where there is too much water, the nitre does not appear. In little valleys and saucer shaped depressions in which the lower portions are too wet, there is no visible alkali, then follows a zone where white alkali abounds and above this the nitre is formed. I do not mean to say that there may not be nitre mixed with the white alkali, but that the nitre in such cases appears on higher ground than that on which the white alkali usually appears. Furthermore, it is not intended that anyone shall infer that it is only in valleys and depressions that the nitre occurs."

In driving through those districts which are suffering with this trouble, the most striking feature to one not conversant with the symptoms is the brownish, black and, to all appearances, wet condition of the soil. This can be seen along both sides of the travelled road, and often extends to the irrigating ditch, or fence on either side, and into the adjoining fields. I think of nothing which describes the color better than the appearance of soil where crude oil has been spilled, as is done frequently in orchards where oil pots have been used in heating, or, if you please, where the roads have been sprinkled with oil. A typical case of this sort is illustrated in Fig. 1, page 4. Considerable disappointment is experienced, however, when this blackened surface soil is examined for it is often found to be a dry crust, rather than a wet one, one-fourth to one-half inch in thickness, underlaid with one or two inches of material of a very mealy character, beneath which the soil looks like any other soil. Sometimes the surface is so moist as to be slippery, due, probably, to the presence of quantities of deliquescent salts. As one walks over a field in this condition and breaks through the hard crust, the sensation experienced has been likened to walking on corn meal or ashes.

Concerning the condition of the soil met with under the mealy layer, I can not go into details since Dr. Headden has treated this phase of the question very fully and completely in his publications, suffice it to say that free water is seldom found nearer to the surface than five feet, and in most cases the soil is in what would be considered a nice moist condition; again in the heavier lands, we may expect and do find them rather sticky near the surface and of a gumbo character as the water plane is approached.

The brown color often appears on the banks of the irrigating ditches, eight to ten inches above the level of the water, and along the upper edge of the irrigation furrows. Extending lengthwise of these, it manifests itself a few days after irrigation as broad bands of pigment which might easily be mistaken for manure stains, so far as color is concerned, especially if the field or orchard had been fertilized recently. It is not uncommon to find large tracts of land where the nitrates have become so abundant as to be deleterious to the crops, yet no discoloration is apparent on the surface. It is difficult to say in such instances whether no color is being produced or whether it is developing so gradually and uniformly that it can not be detected readily.

The economic outlook of this problem is, indeed, a serious one. Bushels of wheat have been planted on heavy nitre soils, and if it germinated at all, only a very small percentage ever came through the ground. Oats and barley have suffered the same fate. Corn has germinated in some fields, and made a sickly, yellow growth of six inches to a foot and then died. Sugar beets, if they grew at all, have gone to tops, while the roots have taken on all sorts of abnormal, irregular shapes, typical "tub-beets," to say nothing of the inferior quality of the beet from the sugar standpoint. Dr. Headden has collected

a great deal of data on this point which will be presented by him in due time. The money loss to the farmers in seed alone has amounted to thousands of dollars. But the orchardist has been unquestionably the heaviest loser, for not only has he been deprived of the crop for the current season, but he has also lost the trees upon which he is dependent for future crops, at least we have yet to see a single tree which has shown any indication of recovery. Added to this and worse than all, perhaps, is the utter worthless and hopeless condition of his soil for agricultural purposes. The apple, cherry, apricot and plum, all appear to suffer about equally, while the pear and peach, thus far, have exhibited marked resistance, the peach having been observed to suffer least of all.

The symptoms of excessive nitre in the soil as manifested in apple trees are so characteristic that it may be well to describe them briefly in passing. The first indication is the firing or burning of the leaves along the margins, beginning at the apex, extending rapidly along the edge, inward toward the midrib and downward toward the base until the entire leaf has turned brown. There is no occasion for anyone who is familiar with the yellowing of foliage due to lack of proper drainage to confuse this with the nitre burning, for the appearance of the leaves in the two cases is entirely distinct. Whole trees have been known to undergo this transformation in less than three weeks time. In fact, Dr. Headden reports having killed a four-year-old tree in an experimental orchard in four days by applying twenty pounds of nitrate of soda around the roots and then irrigating at once to bring the nitre into solution. In reference to the behavior of this tree, he says, "The effects were in all respects similar to those produced in other orchards" under natural conditions. If the burning of the leaves occurs early in the season, the trees will often exert a feeble effort to put forth a second crop of leaves. These are usually small, whitish leaves and inclined to be rather pubescent. Such trees, laden with one-third to one-half grown apples, seldom mature any fruit, and in all probability will be dead by spring. If the attack comes late in August or September, the chances are that the fruit will mature, but it will be undersized and of poor quality; no new leaves will be expected to appear and the old ones will cling to the twigs late into the fall. The following spring, it is very likely that an attempt will be made at leafing out, but as stated above the leaves will be small, yellowish-white and few in number, and by the middle of the season the tree will be dead.

Before proceeding further, I wish to make it perfectly clear that what I have said is not to be interpreted as applying to all of our arable land or to more than a very small percentage. While the matter is eminently serious, it by no means justifies the position that our agricultural interests as a whole are in jeopardy. Just how we shall meet these difficulties, and correct the trouble, we are not prepared to say at present, but we are hopeful. As our knowledge of the subject grows, we feel confident that remedial measures will be forthcoming

in the near future. In this connection, I may say that it is my purpose this coming season to plant several foreign grasses, reputed to be heavy nitrogen feeders, on high nitre soils with the expectation of securing some crop which can utilize the nitrogen.

In order that the reader can have a more definite idea of the amount of nitrates which have been found in some of these once arable soils, I am giving below a few figures on this point which have been furnished to me by Dr. Headden, to whom I am indebted for the soil analyses and many of the soil histories contained in this bulletin.

By way of comparison, I may say that an average amount of nitrate for our cultivated fields is from .000626 to .002005 per cent.

TABLE No. 1. Nitrates in certain Nitre Soils.

Source	Material examined	Percent water soluble	Percent nitrates in water soluble	Percent nitrates in air dried soil
Black spot in barley field.	Surface soil two inches	13.4	41.859	5.628
Young orchard	Surface soil	22.466	29.114	6.54
Young orchard	Surface soil two inches	8.23	8.173	.673
Alfalfa field	Top soil five inches	7.78	33.06	2.571
Oat field	Surface soil two inches	5.42	50.221	2.722
Orchard	Top soil 12 inches	6.51	43.57	2.837
Corn and rye.	Surface soil	4.67	7.352	.342
Old orchard	Surface soil	6.65	5.746	.382

These figures may mean more when I say that one of the above samples, which carried 2.873 per cent of nitrates in the surface foot, contained nitrates corresponding to 113,480 pounds, or 56.74 tons per acre foot; in another sample, taken to a depth of five inches, the area involved being about eight acres, sodic nitrate corresponding to 344,000 pounds or 172 tons was found in the surface five inches; in the top four inches of another eight acre tract, the equiva ent of 189,971 pounds or 95 tons was found.

With such quantities of nitre in the soil as these figures indicate, it seems hardly necessary to look elsewhere for an explanation of the death of our trees and crops.

Because of other investigations which were already under way, I was not able to take up this very interesting question until recently, except to go on occasional, hurried field trips into the districts involved. Here, I saw all that had been described to me, and, I must confess, intensified and more serious than I had imagined.

A very natural explanation for the accumulation of these nitrates, and one which may have suggested itself to the reader, would be the

concentration of the salts from the irrigation and ground waters in the surface layers of the soil. This, of course, presupposes the existence of a nitrate bearing stratum from which to derive this salt. In the first place, no such stratum or bed is known to exist within the state or neighboring states, and, in the second place, our deep well waters, ground waters and surface waters contain an insignificant and negligible quantity of nitrate.

That these spots are the remains of great herds of extinct animals which perished from some unknown cause is highly improbable, first, because the areas involved are too great; second, as mentioned before, the present spots are increasing in size, and, third, spots are appearing today in localities where the trouble has never been reported before.

For the same reasons, there is no ground for believing that these areas are nitre beds related to some established geological horizon.

Unable to account for this phenomenon satisfactorily in any of the foregoing ways, we have been forced to the one remaining possibility, namely, the formation of the nitrates *in situ*.

Having reached this conclusion only after a thorough study of all other possible causes, Dr. Headden presented the question to me as a purely bacteriological problem, amenable to bacteriological methods.

Under ordinary circumstances, I should have looked to the ammonifying and nitrifying flora of our soils as the responsible agents, but the amount of organic matter in our soils, both cultivated and virgin, is far too small to supply the organic nitrogen required for the manufacture of such quantities of nitrate. Confronted by this nitrate monstrosity on the one hand, and by the dearth of nitrogen on the other, I must confess that the question was somewhat perplexing. However, it seemed to me that the logical method of procedure was to look elsewhere than to the soil for a source of nitrogen. Quite naturally, I turned my attention to the atmosphere. If it could be demonstrated that our soils had the power of fixing atmospheric nitrogen through the agency of Azotobacter and did fix it, I felt reasonably certain that it was only a question of time until we could show that the ammonifying and nitrifying organisms were utilizing this new supply of nitrogen to build up nitrates.

With this as a starting point, I have begun my studies on the fixation of nitrogen by Azotobacter in certain Colorado soils.

SCOPE OF PRESENT WORK.

Our studies on the fixation of atmospheric nitrogen, presented herein, have not been confined to fixation in solutions alone, but have been extended to include fixation in the soil itself. Two such soil experiments are reported here, but the greater part of this data has been reserved for another bulletin.

Extended studies on the ammonifying and nitrifying efficiency of these same soils are in progress at the present time, the results of which will constitute the text for a future publication.

GENERAL METHODS.

For determining the nitrogen fixing power of the different soils in solutions, we have used the mannite solution recommended by Lipman[1] except that the tri-basic potassium phosphate, (K_3PO_4), has been substituted for the di-basic, (K_2HPO_4).

Mannite Solution for Nitrogen Fixation.

Tap water	1000.00 c. c.
Mannite	15.00 grams
K_3PO_4	.5 grams
$Mg\ SO_4$	.2 grams
$Ca\ Cl_2$	.02 grams
10 per cent solution $Fe\ Cl_3$	1 drop

This was made neutral to phenolphthalein with normal NaOH. 100 c.c. of this solution containing 1.5 grams of mannite were employed for each soil examined. It was placed in 500 c. c. Erlenmeyer flasks and sterilized in the autoclave for five minutes at 120 degrees C. These solutions were inoculated with 20 c.c. of the given soil infusion corresponding to 10 grams of the soil. The infusion was prepared by mixing 150 grams of soil with 300 c.c. of sterile physiological salt solution (.75% Na Cl), shaking the mixture for five minutes and then allowing it to stand for thirty minutes for the coarser particles to subside, after which the inoculating suspension was withdrawn with a sterile pipette. Four flask cultures were prepared from each soil, two of which were analyzed for total nitrogen immediately, and the remaining two after thirty days' incubation at 28 degrees C.

For isolating and growing our stock cultures we have employed a mannite agar of the same composition as the mannite solution with the addition of 15 grams of agar per 1000 c.c. of solution.

In isolating Azotobacter from the crude soil cultures we have depended solely upon repeated plating for obtaining cultures in a pure condition. We were troubled a great deal with a small bacillus which was almost invariably associated with the Azotobacter colonies in the original plates but by replating through three dilutions, sometimes three different times, we were able to obtain pure cultures. The intermediate glycerine solution recommended by Lipman did not prove satisfactory in our hands.

Our stock cultures of Azotobacter were isolated in March, 1910, and have been transferred every fourteen days since that time on mannite agar.

For determining the total nitrogen in the cultures and in the soils, we have used the Gunning Method modified to include nitrates as described in the Official Methods of Analysis,[2] page 8.

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1. Rept. of Soil Chemist and Bacteriologist, New Jersey Exp. Sta. 1908, p. 137
2. Bulletin No. 107 (Revised) Bureau of Chemistry, U. S. Dept. Agr. 1908.

DISCUSSION OF THE SOILS UNDER STUDY.

NITROGEN FIXING POWER IN SOLUTION.

In order that the reader may have a truer appreciation and a clearer conception of the actual conditions as they exist in the soils about to be described, it has seemed desirable to the writer to accompany each with a brief description of the field or orchard from which the sample was obtained. In several instances, the quantity of nitrate found appears to be in excess of all reason, but when measured by the damage done to vegetation, it falls easily within the limits of possibility. The converse of this proposition is equally true. If we are to witness the destruction of a forty-acre orchard in one season, we shall need to look for some such powerful agent as nitre occurring by the tens of tons to the acre foot.

SAMPLES NOS. 1, 2, 3, 4.

It is needless to say that at the beginnig of our work we encountered unforeseen difficulties. We were dealing with soils which were decidedly unlike other soils, and in which previously unheard of conditions maintained. Naturally, our first samples were taken from those spots where the trouble was unmistakably present, and there was nothing to tell us how concentrated the nitrates might become and still permit the growth of the soil flora. The results obtained with these early samples were rather disappointing inasmuch as they seemed to possess practically no nitrogen fixing power when tested out in mannite solutions. Subsequent work, however, showed that the nitrogen fixing bacteria, as well as the higher forms of plant life, had been destroyed by the nitrates.

After a little experience we were able to establish, in a general way, a relation between the appearance and the nitrate content of a soil, on the one hand, and the probable occurrence of Azotobacter on the other. This made it possible to take samples more intelligently and to avoid the extremely high nitre areas. Samples 1, 2, 3 and 4 will serve very nicely to illustrate the relation of nitrate accumulation to the presence of the nitrogen fixing bacteria. They were collected September 21, 1909.

All four of these were taken from a forty-acre tract, twenty acres of which had been in bearing orchard and the remainder in alfalfa. In 1907 barren spots began to appear in the alfalfa; brown patches, here and there, in the orchard soon became conspicuous, and the trees commenced to die. By 1909, fifty per cent of the orchard had perished along with the entire twenty acres of alfalfa, and in 1910, portions of possibly six rows along one edge and a few trees in a far corner were making their last struggle. The whole center was a barren waste with not a weed to be seen. The greater part was brownish black on the surface, glistening with crystals and to all appearances wet, but, in fact, covered with a hard, dry crust about 3-16 inches thick. Beneath this, the next 1½ to 3 inches were mealy in

character, a mixture of soil and crystals. Below this, the soil grew wet very rapidly and at sixteen inches was practically mud. There was no free water at three feet and in a nearby excavation which had been made for a cellar, over three feet deep, there was no water, yet the soil which varied from a sandy loam to a calcarious clay was decidedly wet and sticky sixteen inches below the surface. It was necessary to dig to a depth of six feet to reach the flow of ground water.

Sample No. 1 was composed of the surface crust of which 12.523 per cent was soluble in water. 19.822 per cent of this, or 1.482 per cent of the air dried soil consisted of nitrates. The flask culture did not develop a typical brown Azotobacter membrane, but rather a whitish yellow scum. This was composed mostly of rod shaped organisms with scattering Azotobacter like forms which disappeared with age. A marked gaseous fermentation of the culture solution took place, accompanied by formation of acetic acid. In thirty days, this soil fixed 1.05075 m. g. of nitrogen.

Sample No. 2 came from the mealy layer beneath the crust; 8.44 per cent of this was water soluble, 15.421 per cent of which or 1.301 per cent of the air dried soil was nitrates. A very delicate, white scum with almost no growth in the body of the liquid was all that was obtained in the culture. There was some fermentation and slight acid production with the odor of butyric ether. In thirty days, the increase in nitrogen was so small as to be practically negligible, being only .5604 m.g.

Sample No. 3 consisted of the twelfth to fourteenth inch inclusive where the ground was wet. Unfortunately I do not have the analysis of this portion of the soil, but in a nearby orchard the fourth to fifteenth inch inclusive contained .676 per cent nitrates. In all probability, my sample carried less than this since it contained a smaller amount of the rich surface material. With this, I secured the Azotobacter forms in a limited number, comparatively speaking, along with the ordinary rods which made up the patchy film and flocculent growth of the culture. Some fermentation and slight acid production with a cheesy odor were observed. An increase of 3.43245 m. g. of nitrogen was obtained after thirty days.

Sample No. 4 came from near a tree along the edge of the affected area. The soil appeared normal and the few trees close by seemed in a healthy condition. The surface two inches were removed and the second to sixth inch inclusive were collected. A typical chocolate brown, wrinkled Azotobacter membrane was obtained with this material in five days. This form was very abundant and dominated in the culture which was slightly acid and possessed an earthy odor. After thirty days, the determination of nitrogen showed an increase of 12.4689 m. g.

A comparison of the results obtained with these four samples suggests that the nitrates were so abundant in the first two that the Azotobacter had either been destroyed or so weakened in virulence that

little or no fixation could be accomplished; that the fourteenth inch sample, while rich in nitrates, did not carry enough to inhibit entirely the growth of the nitrogen fixing bacteria, and that in No. 4, the conditions were very favorable for these organisms.

SAMPLE NO. 5.

This sample was procured September 21, 1909, from an orchard between the irrigating furrows. The brown surface soil, a light clay loam, was removed and a section, including the second to sixth inch, was taken. In 1908 a few of the trees had died and the owner, believing that possibly this had been caused by lack of fertility, had given the orchard a liberal dressing of stable manure. The following spring the ground from which the dead trees had been removed, one to two acres perhaps, along with seven or eight acres of the orchard, was sown to wheat, but to the dismay of all concerned this, too, failed to grow, only a very small per cent ever coming up. During the summer, 1909, fifteen to twenty-year-old trees died by the score, beginning early in the season and continuing late into the fall. A conservative figure for the damage done this year would be the loss of 300 bearing apple trees.

1910 saw a continued spread of the burning, and already in 1911 the attack is being renewed with increased vigor.

In the culture solution, the growth took the form of a dull, almost continuous scum, with patches of white, gelatinous material here and there. There was a slight acid production with the odor of butyric ether at times. The microbic flora consisted principally of large rods, mycelial threads and many clostridium forms resembling closely, if not identical with, Clostridium pastorianum. An increase of 3.0822 m. g. of nitrogen was obtained in thirty days.

SAMPLE NO. 6.

The material for this test was taken from the top of a brown irrigating furrow in a beet field. The surface crust was removed and the next four inches used. The soil was a sandy clay and the field was in alfalfa in 1906. At this time complaints were received of the appearance of bare spots on which the alfalfa was dying out. The largest of these was horse-shoe shaped and about one-half acre in extent. The chief trouble in this instance was seepage but in 1908 the field was sown to oats, and it was not long before a number of brown patches, mealy in character, developed on the higher places. When the land was being prepared for beets in 1909, there was nothing unusual to create one's suspicion except the seepage. I visited the field in September and there were great bare spots surrounded by beets with immense tops. This is shown in Fig. 2, page 13. The stand had evidently been very poor since some of the barren places would average a half acre in area. The soil was mealy and high in nitric acid. That fall the land was sown to winter wheat and when I saw it the next summer, the whole twenty-five acres was a total failure.

My sample was secured in September, 1909, and in thirty days gave a fixation of 3.57265 m. g. of nitrogen. In culture it produced a lemon yellow membrane on the surface with a similar growth in the bottom of the flask. There was a slight acid production accompanied by a butyric, cheesy odor.

Fig. 2. Nitre spot in a sugar beet field. Sample No. 6.

Samples Nos. 7 and 8.

These samples were taken from a deserted field where the brown areas had become very numerous and extensive. The Russian thistles which had been the last inhabitants of these spots had died and left them bare. Adjoining orchards were suffering from the nitrate burning. The trouble was first noticed here in 1908 and in September of 1909 I took my two samples. No. 6 came from a brown spot, five feet in diameter and No. 7 was taken three feet outside this affected area. In both cases the surface two inches were discarded and the next four inches collected. The soil was a red, gypsiferous c ay and no water occurred anywhere near the surface. In culture, these two resembled each other very closely. They produced a yellow membranous growth, with some gas, little acid, and a cheesy odor. No. 7 developed a more typical Azotobacter membrane than No. 8. This was composed largely of the characteristic Azotobacter forms and numerous other small rods and clostridia, but no brown color developed. The membrane produced by No. 8 was not as heavy as No. 7, but was made up of practically the same forms. In thirty days soil No. 7 fixed 3.01215 m. g. and No. 8, 2.87205 m. g. of nitrogen.

Sample No. 9.

All of the samples which had been collected thus far had been from either high nitre spots or immediately adjoining areas, and it seemed

to me quite desirable that we should have a specimen of soil from some locality where this nitrate trouble had not been heard of. It looked only reasonable that if the nitrates were killing apple trees, they were probably also destroying the microbic soil flora, and I wished to have a sample of what might be considered a normal soil as a check. For this purpose we obtained material from an alfalfa field where there was no history of any trouble. The ground was light, well drained, and judging from the size of the plants, it had been in alfalfa for a number of years. The surface two inches were discarded and the next four inches were taken for the sample.

In ten days a heavy, gelatinous, white Azotobacter membrane formed in the culture flask. Azotobacter was the dominant form, but other small rods were also present. There was some fermentation and an odor of rotten cabbage was developed. After thirty days the membrane was brown in color and had the physical appearance of cold grease which has hardened on top of a beef infusion and later has been disturbed and broken. This soil gave an increase in nitrogen in thirty days amounting to 10.15925 m. g. After obtaining this result and a similar one with No. 4, I felt pretty well satisfied that the true nitrogen fixing power of the soil could not be judged from a sample which was taken from either the dark crust of a nitre spot or an area where all vegetation had been dead for some time and where a chemical analysis showed the nitrates to be extremely high. I felt very confident from our work thus far that some of our soils, at least, were stocked abundantly with Azotobacter chroococcum, but it was very evident that this genus had either been destroyed or become greatly attenuated where the nitrates were excessive. I am inclined to accept the former view by way of an explanation since I have plated out crude cultures repeatedly which were made from very bad soils and have failed to obtain anything which resembled Azotobacter. Again I have had no difficulty at all in isolating pure cultures of Azotobacter from crude cultures prepared from soils which were high in nitrates, but not excessively so, and which a month later developed fatal quantities. After my experience with these two samples, I decided to take the soil for future work from areas where the nitre was just beginning to manifest itself on the vegetation and toward which the wave of nitrate destruction was advancing. I am glad to say that I was not disappointed in adopting this new way of sampling as the following experiments will testify.

SAMPLE NO. 10.

In April, 1910, Dr. Headden called my attention to the unmistakable brown stain on the irrigating furrows of a young orchard belonging to the Experiment Station. This was the first indication of the trouble that had been observed in this immediate vicinity. The color was confined to the furrows, there was no mealy condition of the soil and the trees were in perfect health. The soil was a clay loam, well drained, with gravel and ground water at 18 to 20 feet. Up to the pres-

ent time no injury has been observed in the orchard. The same brown color was very marked along the roadside where the irrigating water had been running three days previously. With this soil taken from the furrow, a yellowish brown membrane, consisting largely of Azotobacter, was obtained, and upon analysis the culture showed an increase of 7.7055 m. g. of nitrogen in thirty days.

Sample No. 11.

Sample No. 11 was obtained from an alfalfa field located on river bottom land where the water was quite near the surface. Five to ten acres of alfalfa had died and the barren spots were brown to black on the surface. The soil was a light alluvial formation and admirably suited to agriculture. The top four inches were taken for examination June 1910. In culture it developed a heavy straw colored, leathery membrane, after 48 hours, which was composed of Azotobacter cells with many large and small rods. After thirty days, an increase of 5.11365 m. g. of nitrogen was obtained.

Sample No. 12.

A complaint was received from a certain truck gardener in July 1910, stating that there were places in his garden where, for several years, he had been unable to secure a satisfactory stand. At that time, his chief trouble was with carrots and parsnips. Three to five acres were involved this season, and from the brown appearance of the surface and mealy character to the tread, the soil looked very suspicious. It was a nice sandy loam and no trouble was ever experienced in raising crops except on the barren spots. Even on these, when the plants became once established, they grew very luxuriantly. A sample consisting of the three inches of top soil, taken about ten feet from a barren place, was procured. This yielded a heavy, wrinkled, pale yellow membrane, which browned with age. Azotobacter was abundant and after thirty days our analysis showed an increase of 8.61615 m. g. of nitrogen in the culture.

Sample No. 13.

We come next to an orchard where the burning first appeared in 1909 on the apple trees. The point of particular interest in this case is the marked resistance which a block of pear trees has shown to the nitre. There are about three acres of these trees in full bearing and, although lying adjacent to a five acre apple orchard which is badly affected, and in the direct path of the nitre streak, the first injured pear tree is yet to be seen. As a matter of fact, this immunity of the pear is an occurrence of rather frequent observation. The apple orchard embraced about seven acres and the trees were all from twenty to twenty-five years old. They had been in perfect condition and yielding abundantly until the summer of 1909 when the burned leaves began to make their appearance. A section in the center of the orchard of about one half acre, succumbed that season, but before July, 1910, when I took my sample, three more acres had died and had been pulled up and the

ground planted to corn. This stand was very poor. Much of it died in the ground shortly after germination, while some that did grow, attained a height of 8 to 10 inches, with sickly yellow leaves and finally died. By the end of fall, 1910, approximately 300 trees had been taken out and consigned to the brush heap and wood pile. I have learned recently that the remaining acre and a half began dying so rapidly this spring (1911) that it, too, was grubbed out. Thus, the complete ruin of the seven acres was brought about in less than two years. The soil is a sandy loam, underlaid with gravel at 5 to 8 feet. There is no water near the surface. The characteristic brown color was plainly visible on the crests and sides of the irrigation furrows and it was from one of these that I took the top three inches of soil for examination. Azotobacter developed readily in culture with the characteristic membrane and after thirty days an increase of 4.13295 m. g. of nitrogen was secured.

SAMPLE NO. 14.

The next sample was procured from an orchard where only a few trees showed signs of firing in the early summer of 1910. I visited this place in July, 1910, and it took considerable diligent hunting to find the few scattering trees which were suffering. There were perhaps twenty in all. Today six acres of this orchard are dead from no other cause than nitre. There was no water at five and a half feet and the soil was a nice clay loam. The sample for the fixation test was taken from between two rows of trees which seemed to be as badly affected as any and included the surface three inches. The ground between the trees had been recently cultivated so that any brown stain which might have been visible on the irrigating furrows had been obliterated. There was no indication of excessive nitrates in the soil other than the burned edges of the apple leaves. Pure cultures of Azotobacter were isolated readily from this soil which gave an increase of 6.65475 m. g. of nitrogen in thirty days.

SAMPLE NO. 15.

While looking over the orchard described above I was asked to pass an opinion on some apricot trees in a neighboring orchard. They were large trees, seven in number, and affected in a most peculiar way. The foliage of the entire tree was wilted as if the water supply was cut off; the leaves had a good green color and there was a heavy set of fruit which was just beginning to ripen. A short distance from the trees, I discovered the brown color on the soil which we have come to regard as an important symptom of the nitre trouble. I set about at once to look for signs of this on the apple foliage nearby, and before I had gone far, my search was rewarded. The number of trees involved was limited to possibly a dozen and these were not burned severely. However, by the end of the season, all of these had died and were taken up, leaving about a quarter of an acre barren. There was some indication of too much water in this orchard and it is very possible that the

question of seepage should be taken into consideration here as well as the high nitrates.

A sample, taken near one of the apple trees, showed the soil to be a rather heavy clay loam. In culture it developed a characteristic white, gelatinous Azotobacter membrane and in thirty days gave a nitrogen increase of 10.15725 m. g.

SAMPLE NO. 16.

With Azotobacter as widely distributed as the foregoing sample indicated, there came the natural query, whether this genus was not indigenous to all of our soils in a raw state as well as cultivated. To determine this point I procured my next sample July 13, 1910, from the top of an adobe hill which was above all ditches and consequently was watered only by the scant rainfall. No vegetation was growing here and because of its location and inaccessibility, I have my doubts whether man had ever trod that particular soil before. It was literally raw land in the process of formation. The underlying decomposing shale from which the shallow soil was being made came to the surface in a number of places. The culture solution which was inoculated with an infusion of this material showed only a very slight growth, visible as a slight turbidity and delicate scum. In fact, this may have been due to the infecting substance itself. Microscopic examinations of the solution were made at frequent intervals but nothing which resembled Azotobacter could be detected at any time. After thirty days, there was a slight apparent increase in the nitrogen content of the culture but this was so very small, amounting to only .2802 m. g. that it could be easily accounted for by the personal equation. It was clear from the result obtained here that this virgin soil, at least, possessed neither nitrogen fixing power nor nitrogen fixing flora.

SAMPLES NOS. 17 AND 18.

After testing sample No. 16 and finding that it was practically inert so far as nitrogen fixing power was concerned, we were interested in learning what effect cultivation might have upon such a soil since many of the orchards which have been in cultivation from 15 to 20 years were set out in soil similar to this adobe shale. What is more, it is in those older orchards which have been irrigated longer and cultivated more vigorously that we find the nitre trouble making the most rapid progress. If possible, we wanted to get a soil sample from a young orchard recently set in raw adobe shale, where there had been but a limited amount of cultivation. We were fortunate in securing just such a case. At a distance of perhaps a mile from the adobe hill from which sample No. 16 was taken we found a piece of raw land which had been broken for the first time in the fall of 1909 and set to young apple trees in the spring of 1910. This was watered by a high line ditch in which the water had not been superabundant and consequently it had received but little irrigation, and that during only one season. About the only difference between this land and the adobe

hill was the difference in the physical condition brought about by cultivation to conserve the moisture. Two samples were taken, Oct. 26, 1910, from this orchard, one (No. 17) from between the rows of trees well out in the tract, and the other (No. 18) from a ditch bank where the moisture conditions should have been more favorable for the growth of the soil bacteria. In culture, neither of these soils produced any surface film and gave only a thin, white membrane in the bottom of the flask. The nitrogen determinations after thirty days indicated that the soil from the ditch bank had actually lost nitrogen while the increase with the other was so slight as to be negligible, (.35025 m. g.) If any conclusion can be drawn from the examination of samples Nos. 16, 17, 18 it would seem to indicate that our adobe shale soils both in the raw state and during early cultivation lack nitrogen fixing powers.

SAMPLE NO. 19.

The next sample was taken July, 1910, in a bearing orchard where the burning had appeared for the first time the previous year. There was no well defined area in which one could say that the trouble was worst but it was scattered throughout. In all, about two and one-half acres had been killed when I visited the ranch. The soil is a sandy loam which cultivates beautifully. It is underlaid with gravel at five and a quarter feet in which there is a little water at times. A hole six feet deep was dug in this orchard and allowed to remain open for one year for the purpose of seeing if there was an excess of water in this soil which could be removed by proper drainage. At the end of the time stated, the hole was as dry as the day it was put down. The brown color was plainly visible on the sides and crests of the irrigation furrows and the trees were dying in a manner that we have come to recognize as specific for nitre burning. The sample from this orchard was taken from between the irrigating furrows near a tree that was just beginning to burn. In culture, there developed a heavy gelatinous, white, wrinkled membrane with scattered brown patches. Abundant Azotobacter cells were present. After thirty days, it showed an increase of 9.807 m. g. of nitrogen.

SAMPLE NO. 20.

Although I felt reasonably certain at the outset that we would secure little, if any, fixation with this soil, I was interested in learning whether, when an orchard died in a phenonemally short time, as was true here, the Azotobacter were likewise killed. There were about thirty acres altogether in the orchard, fifteen of which died between June, 1909, and July, 1910. Sample No. 20 was taken from that section which had been destroyed in 1909 and which had received no water during 1910 so that by July the surface was very hard and dry. The soil varied from a sandy loam to a clay loam with no water at six feet. In culture, a delicate, white, membranous film was formed on the surface with some flocculent growth in the liquid. A sour, earthy odor was developed. The increase in nitrogen amounted to only 2.5218 m. g. in thirty days, demonstrating again that the concentration of the

nitrates, which had proven disastrous to the trees, had also had its detrimental effect upon the nitrogen fixing flora.

Sample No. 21.

This sample, a red sandy loam, was taken in an orchard, July 1910, where the conditions were much the same as those described for No. 20. The orchard included about two acres along one side of which ran a twenty foot wash so that every chance for good drainage was afforded. The trees had begun dying here in 1910 and were about all gone by late summer. The soil was brown along the ditch banks and irrigating furrows. In culture a moderately heavy, white film, containing Azotobacter, formed on the surface of the medium and there was some butyric fermentation. The increase in nitrogen after thirty days amounted to 2.8014 m. g.

Sample No. 22.

In this sample we have one of the most severe cases of nitrate destruction which we have ever recorded. Here is a 90 acre orchard which showed the first symptoms in 1908, and today at least forty-five acres are entirely dead or will be by fall. The soil varies from a red clay to a sandy loam and there is no water at five feet. When sampled late in July, 1910, scattering trees were badly affected, but many were showing only a few burned leaves on the water sprouts. The irrigating furrows showed a light brown stain, more especially on the crests than along the sides, since the orchard had been irrigated recently and it was rather difficult to distinguish the brown color from the moist conditions of the furrow. There was little doubt at this time that the trees were in a very dangerous condition but it was hardly expected that in less than a year half of the tract with its fifteen year old apple trees would be waste land. This soil gave a heavy white gelatinous membrane composed mostly of Azotobacter cells and after thirty days the nitrogen of the culture had increased 8.89635 m. g.

Sample No. 23.

We come next to an orchard where the soil is a red clay loam. This is one of the more recent orchards to show the burning and nothing unusual was observed here until July, 1910. At this time very few of the trees were killed outright but many were in the first stages and some were in a very critical condition The area of the orchard was about forty acres and over one half of the trees are dead today. The soil showed almost no brown color when I took my sample, due possibly to the peculiar red color naturally present. I am inclined to believe that at this time the nitrates had not become extremely high or more of the trees would have been killed and we should undoubtedly have seen more of the brown stain. The culture from this sample showed almost no surface growth but a white membrane on the bottom and sides of the flask. Along with this there developed a marked foecal odor. Azotobacter was present in quantity. The increase in nitrogen in thirty days due to fixation amounted to 7.1451 m. g.

SAMPLE NO. 24.

A barley field on the top of a mesa was the next location chosen for our work. This particular tract was selected for several reasons. In the first place, the nitrates had been accumulating here since 1907 and had become so concentrated by this time, July, 1910, that the only place anything would grow was right along the irrigating furrows and even there the grain was very short and thin. Apparently the water in running through these had washed out a little of the nitrate from time to time and so had reduced the salts to a degree of partial tolerance. The soil on top of this mesa, for some reason, is always wet and one not familiar with the topography of the country would be very apt to suggest that the land was seeped by higher irrigation projects. As a matter of fact, this mesa is at least 200 feet higher than the surrounding country and there is no possible chance for seepage in the sense in which the term is ordinarily used. This peculiar condition seems to have resulted from excessive irrigation and a lack of proper drainage. To use a popular expression, the soil has become "water logged." The superabundance of moisture had most certainly favored nitrate production and the agents which were responsible for the coloring matter, for the soil was as black on the surface as crude oil, and as mealy beneath as wood ashes. Before taking a sample, the surface crust and the next two inches were removed and a section, including the fourth to sixth inch inclusive, was obtained. This came from along an irrigating furrow where the barley was making a feeble struggle. In culture, there was almost no surface growth and only a moderate white deposit on the bottom and sides of the flask. A butyric odor was perceptible. I was rather surprised to find that after thirty days there was an increase of 1.68121 m. g. of nitrogen in the culture.

SAMPLE NO. 25.

As a source for the next sample, I selected a truck garden on the outskirts of a mining town. This was thirty-six miles from the nearest case of nitre trouble of which I had knowledge, and so far as I could learn nothing of the sort had ever been observed here either on the soil or the vegetation. The soil chosen was a very light, deep sandy loam which from its proximity to the river, I took to be of alluvial formation. All kinds of vegetables, together with strawberries, were grown here very successfully. The culture produced with this soil gave a heavy gelatinous membrane, light brown in color, and was made up almost entirely of Azotobacter. The increase in nitrogen in thirty days amounted to 5.8842 m. g.

SAMPLE NO. 26.

Sample No. 26 represents the soil of a young orchard in which several of the small trees on the high ground had died in 1910 and others were looking very suspicious. The ground was first broken in the fall of 1908 and set to apples in the spring of 1909. It was irrigated and cultivated thoroughly that season and had been irrigated for the third

time in 1910 when I took my sample Oct. 25. The soil is a clay loam with considerable gravel, in good condition, and so far as I could observe there was no brown color visible although this had been reported as occurring earlier in the season. The land sloped well so there should be ample opportunity for drainage. When introduced into mannite solution, an infusion of this soil produced a heavy, wrinkled surface membrane, with scattering brown patches, the growth being almost exclusively Azotobacter. The increase in nitrogen in this culture was 14.7105 m. g. in thirty days.

SAMPLE NO. 27.

The material for the next study was obtained from an orchard where evidence of nitre was observed for the first time in the summer of 1910. This was an old orchard and a number of the largest trees were very badly injured but not yet dead. There was no indication of the trouble other than the firing of the green leaves. In an adjacent orchard, there had been heavy loss the previous year and all signs pointed to a repetition of the disaster for 1910. The soil was a heavy clay and my sample consisted of the surface two inches taken between two of the affected trees. The culture obtained from the soil infusion of this soil yielded a heavy, wrinkled, surface membrane with isolated brown patches. The increase in nitrogen in the culture in thirty days amounted to 11.3481 m. g.

SAMPLE NO. 28.

The next sample was taken from what had been a young orchard three years previously. It had been given the best of care which may have hastened the appearance of the destroying agents. The tract contained approximately twenty acres sloping gently to the south and west. Some years before it was set to orchard, a reservoir had been built on the northeast corner, the highest point on the place. This was not a success since it was producing a seeped condition in the lower surrounding country and it had to be abandoned. This was about four years before the orchard was planted. The soil is a clayey loam, for the most part, underlaid with a shale. In 1908 the mealy nature of the surface was first observed. At this time Dr. Headden took a sample and states that the conditions did not afford an opportunity for him to judge the color. I have visited this orchard two different times since then and it has so happened each time I have been there that the soil either has been so extremely dry that no color was visible or else it had just been cultivated and all traces on the irrigating furrows had been obliterated. Four acres of the young orchard died in the spring of 1909 and by fall the area involved had nearly doubled. In Oct., 1910, there were scarcely three acres of the original twenty alive. The living trees were all to be found in the five or six rows along the highest side of the tract. When the first injury appeared in 1909, we learned that this same four acres had given trouble in former years, when the land was in alfalfa, so it was to be expected

that this part of the young orchard would be the first to go. As fast as the trees died they were taken up and in 1910 at least twelve acres were sown to corn. Only a very small per cent of this ever reached a height of eighteen inches, and much of it never came through the ground. All over the area involved there are great barren spots, some of them a half acre in extent, where not even a Russian thistle will grow. A two inch surface sample was taken from one of these spots, October 29, 1910, and contrary to expectation my culture developed a yellowish surface membrane with brown patches. Azotobacter was very plentiful. After thirty days the culture showed an increase of 8.6862 m. g. of nitrogen. Inasmuch as all vegetation had refused to grow where the sample was collected, I had rather imagined that the Azotobacter would be killed out as well, and was not anticipating any such active fixation as was secured.

SAMPLES NOS. 29, 30 AND 31.

The next orchard presents, without exception, the most severe case of nitre that has been called to our attention; severe not only in point of destruction, but in rapidity of spread as well. We have seen orchards where the isolated trees and parts of rows were scattered over a large area, but nowhere else have we observed one solid row after another, the entire length of the orchard, go down in rapid succession, as clean as before a forest fire. The original orchard covered about 15 acres of ground sloping gently to the south and, as measured by its producing capacity, was in excellent condition up to the winter of 1909-1910. At this time a spot about twelve feet in diameter appeared at the lower edge of the tract, which the manager stated always looked wet and black in color. Little attention was paid to this until the spring of 1910 when the trees in this vicinity began dying as with nitre. The trouble spread rapidly up hill and back into the orchard so that by the end of the summer 1910 two and one-half acres had been killed and approximately two acres had been taken up.

I visited the ranch on Oct. 29th and found the barren area very wet and boggy in places. The mud was exceedingly sticky and so soft in spots that one would sink down ankle deep in walking over it. Such spots were usually dark brown or black in color and a little higher than the adjacent ground on which a deposit of white alkali had formed following a light snow. I was told that this was the first time the white alkali had been in evidence. The greater part of the barren area was white except for isolated elevated patches and a strip twelve to fifteen feet wide along the upper side which was black. All indications seemed to point to the fact that the portion occupied by the white salts was too wet for the development of the black pigment. That the reader may have some conception of the violence of the attack, I may say that plum trees were pointed out to me which three weeks before were in perfect condition and now were absolutely dead. For four rows back from the edge of the barren area the trees were either

dead or dying (See Fig. 3, Page 23) and beyond these the burning seemed to stop. However, twelve rows farther back on the higher ground I discovered a single tree which was firing. There was a little white alkali nearby but no sign of any brown or black color. I took Sample No. 29 from the surface of the soil near this tree. So far as I could see, this was the only tree in that part of the orchard which was suffering at this time. I visited this same spot January 31, 1911, and the spectacle that greeted me was awful, to express it mildly. Where three months before there was but a single tree affected, there

Fig. 3. Section of an orchard killed by nitre. Photographed October 29, 1910.

were now six to eight acres involved. The soil was brown and very mealy. The orchard manager informed me that most of this change had followed the last irrigation of the orchard which was given about December 1, 1910. He related that three or four days after he had finished irrigating, he noticed a dark brown, oil-like spot ten inches in diameter near the tree from which sample No. 29 was taken and that after twenty-four hours this had increased to twenty-four feet in diameter by actual measurment. In spite of all efforts to break down this testimony by cross examination and conservative suggestions, my informant held firmly to the original statement declaring that there was absolutely no exaggeration. This particular instance most certainly holds all previous records for rapid progress. It was

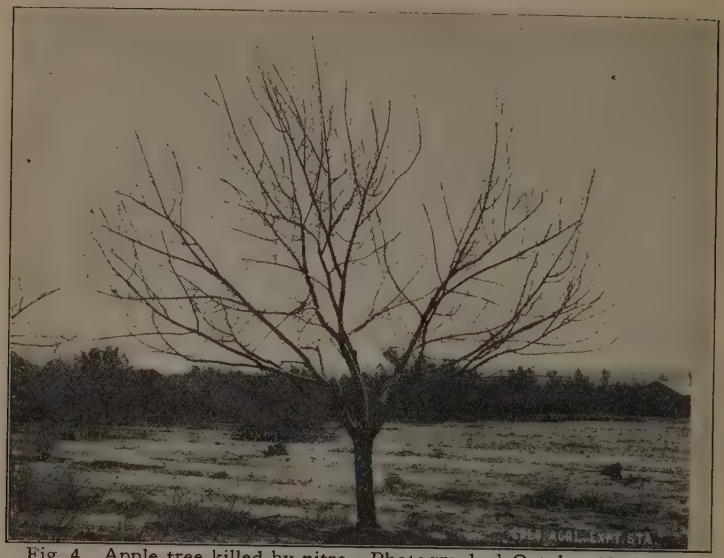


Fig. 4. Apple tree killed by nitre. Photographed October 29, 1910.

Fig. 5. Healthy apple tree located 100 feet from the tree shown in Fig. 4, and photographed on the same day.

from this spot as a focal center that the malady had spread so as to involve eight acres in an entirely new part of the orchard. On April 18, 1911, I looked over this proposition again. There was not a shadow of a doubt in my mind but that the whole fifteen acres were destined to go sooner or later. A conservative figure of the loss up to this date was thirteen acres and the balance were dying. The property had changed hands three times since my first acquaintance with it and the present owner, believing that drainage would relieve the difficulty, expended over $4000 in putting in some 15,000 feet of drain tile. Some little water flows from this drain but as far as ameliorating the condition of the orchard, there seems to be practically no change. Sample No. 30 was taken from one of the black, wet spots mentioned. Since these were of very recent appearance I was interested in knowing whether this intense black color was necessarily an indication of the concentration of the nitrates. On the one hand, if that was true, I should expect to get only a very slight fixation of nitrogen in the culture; on the other hand, if it bore no immediate relation to excessive quantities of the salt, then I would look for larger results.

Sample No. 31 was collected by Dr. Headden, January 5, 1911, from the eight acre section where the nitrates had developed very rapidly since December, 1909. When he handed me the material, he remarked that he would not be at all surprised if I got no results from this soil for it was as brown and mealy as could be. In culture solution all three of these samples gave typical brown, wrinkled surface membranes which a microscopic examination showed to be rich in Azotobacter. With No. 29, taken from near the single affected tree, the increase in nitrogen in thirty days amounted to 10.2273 m. g.; with No. 30, from the black spot, 10.15725 m. g. and with No. 31, 7.9857 m. g. The result from No. 30 would seem to indicate that the black color does not necessarily mean extremely concentrated nitrates. (Figs. 1, 4 and 5.)

SAMPLE NO. 32.

The next sample was taken October 29, 1910, along the road side near the fence, where the soil looked mealy but where there was no discoloration, which could be accounted for probably by the dry condition of the soil. This spot was selected because the road mentioned ran alongside a young orchard where the trees had been dying from some unknown cause. There was such a combination of factors at work in the orchard, namely, neglect, drought and possibly nitre that it was hardly safe to venture an opinion on the cause of the death of the trees. An alfalfa field adjoining this tract showed many barren spots which were suggestive at least. In culture, this soil developed a heavy, tough, brownish membrane, rich in Azotobacter and after thirty days gave an increase of 15.411 m. g. of nitrogen.

TABLE No. 2. Summary of Nitrogen Fixing Power of Soils, Numbers 1 to 32, in Mannite Solution.

Sample No.	Source	Date of Collection	Date of Examination	Date of Completion	Milligrams Nitrogen at beginning	Milligrams Nitrogen at end	Milligrams Nitrogen fixed per 1.5 grams Mannite, 30 days
1	Orchard—surface crust ¼ inch	Sept. 21, 1909	Oct. 5, 1909	Nov. 4, 1910	4.48320	5.53395	1.05075
2	Orchard—4th to 6th inch	Sept. 21, 1909	Oct. 5, 1909	Nov. 4, 1909	.84060	1.40100	.56040
3	Orchard—12th to 14th inch	Sept. 21, 1909	Oct. 5, 1909	Nov. 4, 1909	.77055	4.2030	3.43245
4	Orchard—surface removed 2nd to 6th inch	Sept. 21, 1909	Oct. 5, 1909	Nov. 4, 1909	1.12080	13.5897	12.46890
5	Orchard—surface removed 2nd to 6th inch	Sept. 21, 1909	Oct. 5, 1909	Nov. 4, 1909	.98070	4.06290	3.08220
6	Beet field—irrigating furrow, 2nd to 6th inch	Sept. 22, 1909	Oct. 5, 1909	Nov. 4, 1909	1.75115	5.3238	3.57265
7	Deserted land—barren spot, 2nd to 6th inch	Sept. 24, 1909	Oct. 5, 1909	Nov. 4, 1909	3.08220	6.09435	3.01215
8	Same as No. 7—outside barren spot, 2nd to 6th inch	Sept. 24, 1909	Oct. 5, 1909	Nov. 4, 1909	3.0822	5.95425	2.87205
9	Alfalfa field—normal, 2nd to 6th inch	Sept. 24, 1909	Oct. 5, 1909	Nov. 4, 1909	1.54110	11.69835	10.15725
10	Orchard—edge of irrigating furrow, surface 2 inches	April 26, 1910	April 27, 1910	June 26, 1910	.9807	8.6862	7.7055
	Alfalfa field—						

TABLE No. 2 (Continued) Summary of

Sample No.	Source	Date of Collection	Date of Examination	Date of Completion	Milligrams Nitrogen at beginning	Milligrams Nitrogen at end	Milligrams Nitrogen fixed per 1.5 grams Mannite, 30 days
12	Truck garden—surface 3 inches	July 4, 1910	July 4, 1910	Aug. 3, 1910	5.39385	14.01	8.61615
13	Orchard—surface 3 in. from irrigating furrows	July 13, 1910	July 23, 1910	Aug. 22, 1910	.63045	4.76340	4.13295
14	Orchard—surface 3 in. from irrigating furrows	July 13, 1910	July 23, 1910	Aug. 22, 1910	.07005	6.72480	6.65475
15	Orchard—surface 3 in. from irrigating furrows	July 13, 1910	July 23, 1910	Aug. 22, 1910	.35025	10.50750	10.15725
16	Raw land from adobe hill—surface 3 inches	July 13, 1910	July 23, 1910	Aug. 22, 1910	.00000	.28020	.28020
17	Young orchard on adobe shale—surface 2 inches along ditch.	Oct. 26, 1910	Nov. 9, 1910	Dec. 9, 1910	1.33095	.7005	0.0000
18	Same as No. 17—surface 2 inches between trees	Oct. 26, 1910	Nov. 9, 1910	Dec. 9, 1910	.49035	.8406	.35025
19	Orchard—surface 3 in. between irrigating furrows	July 1, 1910	July 23, 1910	Aug. 22, 1910	.4203	10.22730	9.80700
20	Orchard—surface 3 in. between trees	July 16, 1910	July 23, 1910	Aug. 22, 1910	.70050	3.22230	2.52180
21	Orchard—surface 2 in. from irrigating furrow	July 14, 1910	July 23, 1910	Aug. 22, 1910	.28080	3.08220	2.80140

TABLE No. 2, (Continued). Summary of Nitrogen Fixing Power of Soils, Numbers 1 to 32, in Mannite Solution.

Sample No.	Source	Date of Collection	Date of Examination	Date of Completion	Milligrams Nitrogen at beginning	Milligrams Nitrogen at end	Milligrams Nitrogen fixed per 1.5 grams Mannite, 30 days
29	Orchard—surface 2 in. from irrigating furrow	July 14, 1910	July 23, 1910	Aug. 22, 1910	.21015	9.10650	8.89635
23	Orchard—surface 3 in. between irrigating furrows	July 16, 1910	July 23, 1910	Aug. 22, 1910	.35025	7.49535	7.14510
24	Barley field—black surface 3 inches near irrigating furrow	July 20, 1910	July 23, 1910	Aug. 22, 1910	.35025	2.03146	1.68121
25	Truck patch—normal, surface 3 inches	July 21, 1910	July 23, 1910	Aug. 22, 1910	.42030	6.30450	5.88420
26	Young orchard—surface 3 inches	Oct. 26, 1910	Nov. 9, 1910	Dec. 9, 1910	.2802	14.9907	14.7105
27	Orchard—surface 3 inches	Oct. 26, 1910	Nov. 9, 1910	Dec. 9, 1910	.4203	11.7684	11.3481
28	Young Orchard—surface 3 inches	Oct. 26, 1910	Nov. 2, 1910	Dec. 2, 1910	.35025	9.03645	8.68620
29	Orchard—surface 2 inches	Oct. 29, 1910	Nov. 2, 1910	Dec. 2, 1910	.4203	10.6476	10.2273
30	Same as No. 29—surface inch of black spot	Oct. 29, 1910	Nov. 2, 1910	Dec. 2, 1910	3.29235	13.4496	10.15725
31	Same as No. 29—mealy surface 3 inches	Jan. 5, 1911	Jan. 6, 1911	Feb. 5, 1911	.49035	8.47605	7.98570
32	Orchard roadside—mealy soil under [illegible]	Oct. 29, 1910	Nov. 2, 1910	Dec. 2, 1910	.4203	15.8313	15.4110

While it may be early to state any conclusions, even tentatively held, the foregoing work suggests the following:

1. Excessively high nitrates in the soil will kill the Azotobacter flora.

2. A limited amount of soil nitrate does not seriously affect the nitrogen fixing power of a soil.

3. Our adobe shale soils, both in the raw state and when newly cultivated, possess little if any nitrogen fixing power.

4. The nitrogen fixing power of our soils is not limited to any geographical locality or class of soils, however, the degree of activity may vary.

5. The power to fix atmospheric nitrogen is a property common to many cultivated Colorado soils.

6. Azotobacter chroococcum appears to be the dominant nitrogen fixing agent.

THE NITROGEN FIXING POWER OF SOILS IN SITU.

Having satisfied ourselves that certain Colorado soils possessed the power of fixing atmospheric nitrogen in solutions, the next point on which we wished to inform ourselves was whether these same soils had the power of fixing nitrogen *in situ*. If that could be demonstrated, it would be a relatively simple matter to explain the high nitrates, for, given the proteid nitrogen from which to make the nitrates, we felt reasonably certain that the ammonifying and nitrifying flora would take care of the conversion.

For this part of the investigation two samples of soil were selected at random, one from the central part of the state, and the other from the northern. Both were from localities where either the nitre trouble or the brown stain had been observed. The nitrogen fixing power of these soils was determined independently by two different workers, the northern Colorado sample by Dr. Headden, and the central by the writer. The soils were not handled in the same way by the two of us, so it may be well to discuss our respective manipulations. Other soils have been studied but these two are of particular interest since the results were obtained independently in different laboratories.

Northern Sample.

This soil was collected by Dr. Headden, December 12, 1910, from the young orchard designated as No. 10 in the preceding series. It was screened in a moist condition through a twenty-five mesh wire screen and 1200 grams of the moist soil, with no further treatment, were placed in a deep culture basin (10 in. x 2 in.) and pressed down firmly. The soil moisture was determined and sufficient boiled distilled water was added to make eighteen to twenty percent moisture. This was maintained throughout the experiment. The soil was incubated for twenty-seven days in the dark at 28°C. to 30°C. at the end

of which time samples were removed for analysis and the total nitrogen determined. This showed a gain of 10.54 m. g. of nitrogen per 100 grams of soil for the 27 days.

I am indebted to Dr. Headden for the following results:
Total nitrogen at the end of 27 days - 117.79 m. g. per 100 g. soil.
Total nitrogen at the beginning, - 107.25 m. g. per 100 g. soil.
Total nitrogen gained by fixation in 27 days, ---------- 10.54 m. g. per 100 g. soil.

Assuming that the fixation, under field conditions, proceeds uniformly at this same rate for six months, it would mean an addition of 475.26 pounds of nitrogen or 2,970.41 pounds of protein per month for every acre foot, and in six months, this would amount to 2,851.60 pounds of nitrogen or 17,822.50 pounds of protein, while in a year, we should have 5,703.20 pounds of nitrogen or 35,645.00 pounds of protein per acre foot. With this increase of 2.85 tons of nitrogen or 17.82 tons of protein per acre foot in one year, there certainly need be no cause for anxiety over a source of nitrogen for high nitrate formation.

Central Sample.

This soil was collected by the writer December 30, 1910, and was from the same source as the sample designated as No. 29 of the preceding series. The soil was first air dried and then passed through a 40 mesh wire screen. The moisture was determined and found to be 2.1 per cent. Sufficient sterile distilled water was next placed in a deep culture dish (100 m. m. x 30 m. m.) to give 100 grams of the air dried soil a water content of 10 per cent. 100 grams of the soil were next added to the water in the culture dish and the weight of the whole was determined. This weight was kept constant by daily additions of sterile distilled water throughout the experimental period. The soil was incubated in the dark at 28°C. to 30°C. for thirty days at the end of which time samples were removed and the total nitrogen determined. For every 100 grams of soil there was an increase of 8.22 m. g. of nitrogen in thirty days.

Total nitrogen at the end of 30 days, - - 82.11 m. g. per 100 g. soil
Total nitrogen at the beginning, - - - 73.89 m. g. per 100 g. soil
Total nitrogen gained by fixation in 30 days, 8.22 m. g. per 100 g. soil

Considering that the fixation, under field conditions, proceeds uniformaly at this same rate for six months, it would mean an additon of 333.60 pounds of nitrogen or 2,085.00 pounds of protein per month for each acre foot, or in six months this would amount to 2,001.60 pounds of nitrogen or 12,510.00 pounds of protein, while in one year we should have 4,003.2 pounds of nitrogen or 25,020.00 pounds of protein. Expressing this in tons per acre-foot per annum, we get an increase of 2.001 tons of nitrogen or 12.5 tons of protein.

Table No. 3. Summary of Fixation of Nitrogen in Soils in Situ.

Source of Sample	Duration of Experiment	Milligrams nitrogen per 100 g. soil at beginning.	Milligrams nitrogen per 100 g. soil at end.	Milligrams nitrogen fixed per 100 g. soil
Northern Colorado	27 days	107.25	117.79	10.54
Central Colorado	30 days	73.89	82.11	8.22

Table No. 4. Increase in Nitrogen per 100 g. of Soil.

Source of sample	Increase in nitrogen per 100 g. soil as					
	Milligrams nitrogen		Milligrams protein		Milligrams $NaNO_3$	
	1 month	1 year	1 month	1 year	1 month	1 year
Northern Colorado	11.88	142.58	74.26	891.12	72.08	865.14
Central Colorado	8.34	100.08	52.12	625.50	50.60	607.26

Table No. 5. Increase in Nitrogen per Acre-foot of Soil.

Source of sample	Increase in nitrogen per acre-foot of soil as					
	Pounds nitrogen		Pounds protein		Pounds $NaNO_3$	
	1 month	1 year	1 month	1 year	1 month	1 year
Northern Colorado	475.26	5,703.20	2,970.41	35,645.00	2,883.82	34,605.87
Central Colorado	333.60	4,003.2	2,085.00	25,020.00	2,024.21	24,290.61

Relation of Soil Moisture to Fixation of Nitrogen in Soil.

It has been a matter of frequent observation that where there is an excess of water, as in land which is unquestionably seeped, or where there is a liberal coating of white alkali on the surface, a condition indicative of poor drainage, neither the brown color nor the high nitrates are to be found. However, along the margin of such areas on the higher ground where there is an abundant supply of moisture but not too much, we are apt to find both the high nitrates and the brown color. These two conditions, we have come to associate with the presence of the nitrogen fixing organisms in the soil, and the resulting nitrogen fixing power of that soil. We do not mean to say that they are, by any means, a necessary accompaniment, yet they are very often found together, and from certain experiments which we have made, directed especially toward this feature of the problem, we are led to believe that the relation existing among these three factors is a dependent one.

One step toward the proof of this lay in the demonstration of the relation of the moisture content of the soil to the fixation of nitrogen. To this end, six deep culture dishes were prepared with varying amounts of sterile distilled water each containing sufficient to give 100 grams of air dried soil with a moisture content of 2.1 per cent the following degrees of moisture: 2.1, 10, 20, 25, 30, and 48 per cent respectively. 100 grams of air dried soil which was known to possess nitrogen fixing powers *in situ* were added to each dish. It will be noted that the first dish contained the air dried soil only, while the last, with 48 per cent water, was saturated. The weight of each dish and its contents was determined, and every day the loss of water by evaporation was restored with sterile distilled water. The soils were all kept in the incubator at a temperature of 28°C. to 30°C. for thirty days at the end of which time the total nitrogen was determined for each. The results of the experiment are given in Table No. 6.

TABLE No. 6. Relation of Soil Moisture to Nitrogen Fixation in Soil.

Per cent moisture	Milligrams nitrogen per 100 g. soil		Milligrams nitrogen fixed per 100 g. soil in 30 days
	At beginning	After 30 days	
2.1	73.89	78.84	4.95
10.0	73.89	82.11	8.22
20.0	73.89	80.90	7.01
25.0	73.89	79.13	5.24
30.0	73.89	78.49	4.60
48.0	73.89	73.85	....

The experiment indicates that the optimum moisture content for maximum fixation lies between 10 per cent and 20 per cent; that the amount of fixation gradually decreases as the saturation point of the soil is approached at which it is zero. These results are in perfect harmony with our field observations which have pointed clearly to the detrimental effect of excessive moisture both on the production of brown color and the formation of high nitrates.

THE RELATION OF NITRATES AND AZOTOBACTER CHROOCOCCUM TO THE BROWN COLOR.

The continual occurrence of the brown color on high nitre soils, which have been shown to possess nitrogen fixing power, is too constant an association to be regarded as a mere accident or coincidence. This relation needs no further exposition since it has been referred to repeatedly in the preceding pages, but before entering into any discussion of the subject, it should be understood clearly and emphatically that we have no intention of appealing to the nitrates or the nitrogen fixing flora of the soil to explain *every* brown spot or similar discoloration that may be found. There are at least two other recognized agents that may be responsible for a similar condition. I refer to the

well known Black Alkali of the Southwest in which sodium carbonate is the active principle in bringing the soil humus into solution, which solution, being highly colored, may give the surface a dark appearance. Again there are some soils which contain sufficient quantities of calcium chloride to absorb enough moisture to impart a dark color to the soil. I have Dr. Headden's statement that none of the soils which are concerned in this project contain enough of either sodium carbonate or calcium chloride to account for this phenomenon. Our problem is manifestly different from either of these.

In our pure culture studies of the Azotobacter flora of these soils, we have isolated what appear, in the final analysis, to be six or seven varieties of Azotobacter chroococcum. Three of these, at one time or another, have produced the characteristic brown color on mannite agar. One of these, No. 3, has maintained this character undiminished since it was first isolated; the second, No. 93, acquired the color three weeks after isolation, retained it for six weeks and then lost it; the third, No. 1, has produced a small amount of a light brown pigment at times ever since its isolation but there has been nothing constant in this respect until the last six weeks when it has begun to produce a heavy dark brown color. Three of the remaining four cultures, Nos. 4, 8 and 10, have been characterized by their spreading nature and their abundant, moist, raised, gelatinous, starchy white to yellowish growth on mannite agar. Morphologically and culturally, these three possess such differences as seem to make them distinct from one another; the fourth, No. 13, differed from all the rest in the production of a delicate cream colored pigment; it was spreading in habit but flat, not gelatinous and grew only moderately well on mannite agar. Unfortunately, this culture was lost early in our work, and consequently it has been given no consideration in this treatise beyond mere mention.

The brown color of cultures 1, 3, and 93 served to identify them beyond reasonable doubt as Azotobacter chroococcum. The other four cultures were left unclassified, for the time being, except to place them in the genus Azotobacter after they had been shown to possess nitrogen fixing powers in pure culture.

The close resemblance between the brown pigment formed by some of our cultures and the brown color present on certain soils was suggestive to say the least. It seemed reasonable to me that there might be something peculiar to our soils which could stimulate and intensify the pigment producing power of Azotobacter chroococcum.

To determine this, a number of synthetic agars were prepared, the composition of which was based upon the water soluble salts present in a certain nitre soil. The carbon was supplied in the form of mannite. Each agar differed from every other in the omission of one of the compounds, our object being to determine by elimination, if possible, if any one constituent was directly responsible for the brown pigment. The analysis of the water soluble salts in the soil which was

used as a basis for preparing the different agars, together with the composition of the various solutions from which the agars were made is given below. The solid medium was prepared by adding 15 grams of agar to each 1000 c. c. of solution.

**Water soluble salts in soil used as a basis for synthetic agars.*

	Per Cent
$Ca\ SO_4$	15.902
$Mg\ SO_4$	2.942
$K_2\ SO_4$	3.387
$Na_2\ SO_4$	15.264
$Na_2\ CO_3$	4.813
Na Cl	34.145
$Na\ NO_3$	22.781
Silicic Acid	.252
Loss (water, organic matter, etc.)	.471

The water soluble amounted to 2.97 per cent of the air dried material.

Solution lacking Calcium Sulphate ($Ca\ SO_4$)

Distilled water	1000.00	c. c.
$Na_2\ SO_4$	9 0668	grams
$Na_2\ CO_3$	2.8589	grams
Na Cl	20.2621	grams
$Na\ NO_3$	13.5319	grams
$K_2\ SO_4$	2.0118	grams
$Mg\ SO_4$	1.7475	grams
Mannite	15.0000	grams

Solution lacking Sodium Carbonate ($Na_2\ CO_3$)

Distilled water	1000.00	c. c.
$Ca\ SO_4$	9.4457	grams
$Na_2\ SO_4$	9.0668	grams
Na Cl	20.2621	grams
$Na\ NO_3$	13.5319	grams
$K_2\ SO_4$	2.0118	grams
$Mg\ SO_4$	1.7475	grams
Mannite	15.0000	grams

Solution lacking Sodium Chloride (NaCl.)

Distilled water	1000.00	c. c.
$Ca\ SO_4$	9.4457	grams
$Na_2\ SO_4$	9.0668	grams
$Na_2\ CO_3$	2.8589	grams
$Na\ NO_3$	13.5319	grams
$K_2\ SO_4$	2.0118	grams
$Mg\ SO_4$	1.7475	grams
Mannite	15.0000	grams

*Furnished by Dr. Headden. Bul. 155, p. 17, Analysis XV, Colo. Exp. Sta.

Solution lacking Sodium Nitrate ($Na\ No_3$.)

Distilled water	1000.00	c. c.
Ca SO_4	9.4457	grams
$Na_2\ SO_4$	9.0668	grams
$Na_2\ CO_3$	2.8589	grams
Na Cl	20.2621	grams
$K_2\ SO_4$	2.0118	grams
Mg SO_4	1.7475	grams
Mannite	15.0000	grams

Solution lacking Sodium Sulphate ($Na_2\ SO_4$)

Distilled water	1000.00	c. c.
Ca SO_4.	9.4457	grams
$Na_2\ CO_3$	2.8589	grams
Na Cl	20.2621	grams
Na NO_3	13.5319	grams
$K_2\ SO_4$	2.0118	grams
Mg SO_4	1.7475	grams
Mannite	15.0000	grams

Solution lacking Magnesium Sulphate ($Mg\ SO_4$)

Distilled water	1000.00	c. c.
Ca SO_4	9.4457	grams
$Na_2\ SO_4$	9.0668	grams
$Na_2\ CO_3$	2.8589	grams
Na Cl	20.2621	grams
Na NO_3	13.5319	grams
$K_2\ SO_4$	2.0118	grams
Mannite	15.0000	grams

Solution lacking Potassium Sulphate ($K_2\ SO_4$)

Distilled water	1000.00	c. c.
Ca SO_4	9.4457	grams
$Na_2\ SO_4$	9.0668	grams
$Na_2\ CO_3$	2.8589	grams
Na Cl	20.2621	grams
Na NO_3	13.5319	grams
Mg SO_4	1.7475	grams
Mannite	15.0000	grams

Solution lacking Mannite ($C_6H_{14}O_6$)

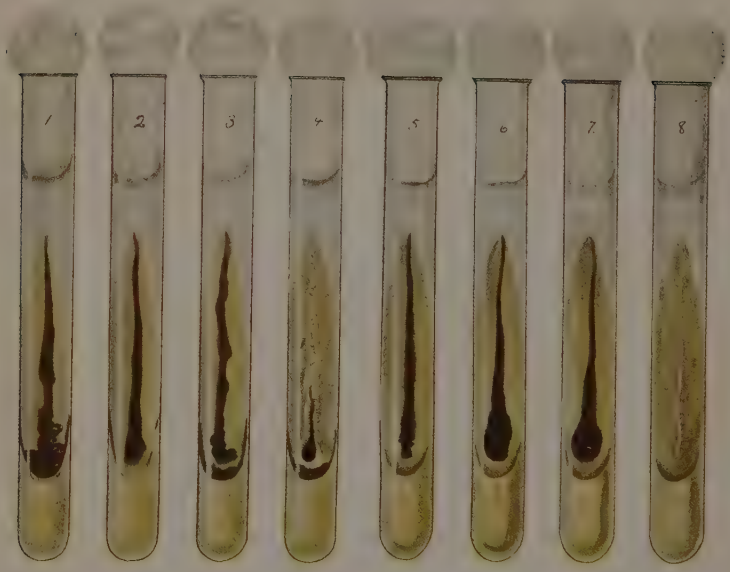
Distilled water	1000.00	c. c.
Ca SO_4	9.4457	grams
$Na_2\ SO_4$	9.0668	grams
$Na_2\ CO_3$	2.8589	grams
Na Cl	20.2621	grams
Na NO_3	13.5319	grams
$K_2\ SO_4$	2.0118	grams
Mg SO_4	1.7475	grams

The chemical reaction of these solutions was left unchanged. Agars of four different strengths were prepared from each solution by diluting the solution once, twice and three times with an equal volume of distilled water. The resulting agars, then, contained the

Table No. 7. Growth and Pigment Production on Synthetic Soil Agars.

Culture	Synthetic Agar lacking							
	$CaSO_4$		Na_2SO_4		Na_2CO_3		Na Cl	
	Growth	Pigment	Growth	Pigment	Growth	Pigment	Growth	Pigment
No. 3.	moderate	brown	moderate	brown in spots	moderate	chocolate brown	moderate	brown
No. 8.	moderate	black	moderate	deep chocolate brown	moderate	black	moderate	chocolate brown
No. 93	moderate	chocolate brown	moderate	chocolate to black	moderate	chocolate to black.	moderate	chocolate brown
A. chroococcum.	moderate	dark brown to black	moderate	dark brown to chocolate	slight	none	slight	light brown

Culture	Synthetic Agar lacking							
	$NaNO_3$		K_2SO_4		$MgSO_4$		Mannite	
	Growth	Pigment	Growth	Pigment	Growth	Pigment	Growth	Pigment
No. 3	slight	none	moderate	chocolate brown	moderate	chocolate brown	very slight	none
No. 8	moderate	few dark brown specks	moderate	black	moderate	black	very slight	none
No. 93	moderate	few brown specks at bottom of streak	moderate	dark brown	moderate	black	very slight	none
A. chroococcum.	slight	none	moderate	dark brown	moderate	dark brown	very slight	none



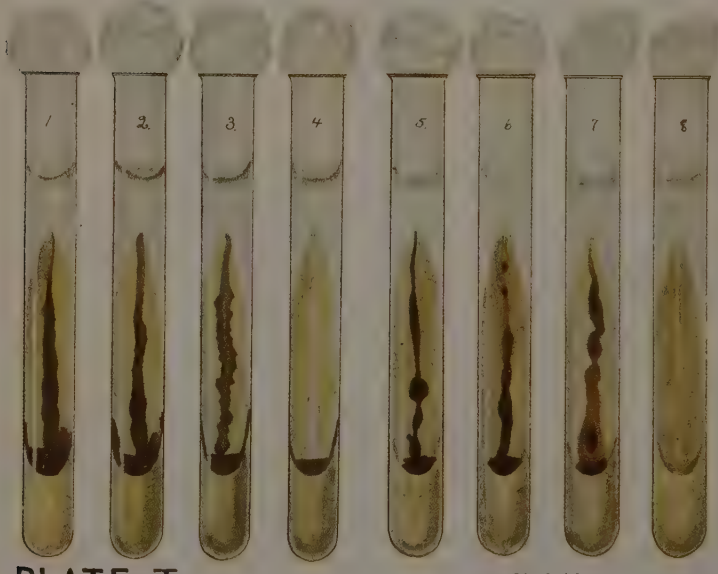


PLATE I

COLO. AGRL. EXPT. STA.

above solutions in the following amounts in which S represents the original strength: S, S÷2, S÷4, S÷8.

The agar was placed in test tubes, using about 7 c.c. per tube, and sterilized for 5 minutes in the autoclave at 120°C.

Streak cultures were next made on each agar of each strength, using cultures Nos. 3, 8, 93 and a stock culture of A. chroococcum. It will be remembered that No. 3 had retained its pigment producing power since isolation, No. 93 had lost it and No. 8 had shown little if any color beyond a dirty white. The results of these inoculations, when observed after fifteen days, are given in Table No. 7.

The best growth as well as pigment was secured on those agars represented by the formulae S÷4 and S÷8.

An inspection of the above table, No. 7, shows very clearly that the two limiting factors in the pigment production are sodium nitrate and mannite. The growth obtained on the agar lacking mannite was so very slight that it was, indeed, difficult to say whether there was any actual growth or whether it was just the line of the original transfer. This was not the case in the agar lacking sodium nitrate. The line of inoculation was well defined in all and in two there was a moderately heavy growth. There was absolutely no brown color but only a dirty white with culture No. 3 and the stock culture of A. chroococcum. In culture No. 8, there was a small amount of brown pigment at the bottom of the streak, and in the water of condensation, the remainder of the growth being dirty white; culture No. 93 contained a few brownish specks in the water of condensation, which under ordinary circumstances would have been overlooked; the streak proper was dirty white in color. Without exception, all the cultures produced abundant chocolate brown to black pigment on all the different agars except those lacking mannite and sodium nitrate. I feel that we are not begging the question when I make the statement that the reason we obtained no pigment in the absence of mannite was because we had no growth. To me, it was perfectly clear from the results of this series, that given a source of energy, the nitrate was the limiting factor in the formation of the dark brown color. I am not prepared to say, just now, whether the nitrate acts as a stimulant to growth, pure and simple, or whether it exercises an oxidizing function on certain bacterial products.

The results of this study were so striking and so self convincing that I have had two sets of the cultures reproduced in colors as nearly like the originals as possible. These were made from 20 day cultures by Miss Palmer, the Station artist. The upper set in Plate I, shows Culture 8, the lower, Culture 93. The numbers 1, 2, 3, etc. on the tubes indicate the composition of the agar as follows:

1. Lacking $CaSO_4$
2. Lacking Na_2CO_3
3. Lacking Na Cl
4. Lacking $NaNO_3$
5. Lacking Na_2SO_4
6. Lacking $MgSO_4$
7. Lacking K_2SO_4
8. Lacking Mannite.

By a system of elimination, we have shown above, that in the absence of nitrates there is practically no pigment formation. I was interested next in knowing just how necessary the other salts were to the production of the brown color, and whether the nitrates alone might not give the desired result. In order to determine this last point, a stock glucose agar was prepared as follows:

Stock Glucose Agar.

Tap water	1000 c. c.
Glucose	20 grams
Agar-agar	20 grams

Glucose was substituted for mannite since two of my cultures produced pigment on the standard mannite agar, and it was determined experimentally that if this substitution was made in the stock agar, practically no color resulted with any of the cultures. By doing this all brown pigment producing factors were eliminated, and I had a medium which would support growth and to which the limiting compounds could be added.

A 10 per cent solution of $NaNO_3$ was prepared in distilled water and sufficient quantities of this were added to different lots of the stock glucose agar to give them a $NaNO_3$ content of 0.0, .01, .03, .05, .08, 0.1, 0.3 and 0.5 per cent respectively. In a 10 per cent solution of $NaNO_3$, 0.1 c. c. contains .01 grams of $NaNO_3$. In order to obtain the above percentages, the following amounts of this 10 per cent solution were added to respective 50 c. c. lots of liquified stock glucose agar: 0.0, .05 c. c., 0.15 c.c., 0.25 c.c., 0.4 c.c., 0.5 c.c., 1.5 c.c., and 2.5 c.c. The agar was placed in test tubes, sterilized for five minutes at 120°C. in the autoclave and slanted. Agar stroke inoculations were made on these with cultures Nos. 1, 3, 4, 8, 10, 93 and stock A. chroococcum

Our results with the series were gratifying beyond expectation. At the end of fourteen days, we had secured either an intense chocolate brown or a black pigment with every one of our cultures on those agars which contained the $NaNO_3$, but absolutely none on the control. The pigment varied in intensity with the amount of $NaNO_3$ present, the optimum quantity for the darkest pigment being between .05 and .08 per cent. In the early growth of the cultures a very nice gradation could be seen in the intensity of the colors, beginning with none in the control, a light brown in the .01 per cent, and a shade darker in each tube as the amount of $NaNO_3$ increased until the deep chocolate brown or black was reached at .05 and .08 per cent after which the shade of brown became somewhat lighter and remained almost constant. With age, this gradation of color was lost, all tubes except .01 and .03 per cent, showing an almost uniformly dark chocolate brown or black pigment. Plate II, prepared from twenty day cultures, illustrates culture No. 8 of this series. Beginning at the left hand side, the tubes contain 0.0, .01, .03, .05, .08, 0.1, 0.3 and 0.5 per cent of

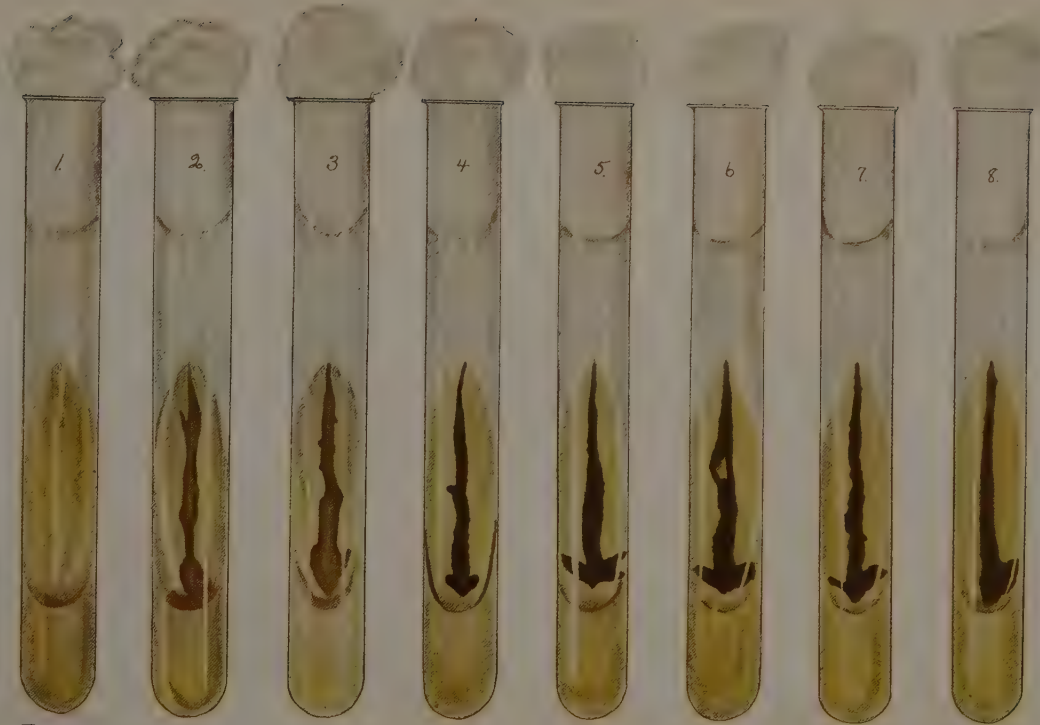


PLATE II

COLO. AGRL. EXPT. STA.

$Na\ NO_3$ respectively. After one has seen this experiment there can be no questioning the fact, that given a supply of carbon, $Na\ NO_3$, of and by itself, can cause A. chroococcum to produce a chocolate brown to black pigment.

This observation is substantiated by the work of Beijerinck[1] in which he has shown that "Pigment formation could also be observed in pure cultures if the mannite was replaced by dextrose and *nitrate* in minimum quantities was added." In the application of these results to field conditions, we have a very tenable explanation of the brown color of the soil. It has been shown that these soils are abundantly stocked with Azotobacter chroococcum, and in the presence of the large amount of nitrates which they carry, the inevitable consequence must be the production of an intensely brown pigment, which has brought the brown spots to our attention.

In 1904 Heinze[2] expressed the view that possibly the dark color of soil was due in a degree to the pigment of A. chroococcum. Lohnis[3] was not inclined to accept this statement, but Omeliansky and Ssewerowa[4] are of the opinion that while it would be a mistake to attribute the dark color of soils to this cause altogether, one has no right to deny the possibility of its occurrence. They have shown experimentally that a brown pigment is produced by Azotobacter in a medium containing chalk and hydrolized starch, both of which are present in soils as $Ca\ CO_3$ and as decomposed plant tissue respectively. Therefore, they concluded that, "The part which Azotobacter plays in the dark color of the soil is not to be overlooked."

The intensely brown pigment which all of our cultures have shown in this and the preceding series seems to identify them all as varieties of A. chroococcum, and consequently they may be considered as such in this bulletin. The variation which has been noted before is in perfect harmony with the observations of Omeliansky and Ssewerowa[5] who state that, "Between the colored and colorless, intermediate forms exist in which the pigment formation is more or less limited."

The Relation of Nitrogen Compounds other than Nitrates to the production of Brown Pigment.

Now if nitrates by themselves can bring about pigment production, may not the same be equally true of other forms of nitrogen? To answer this question, a number of different agars were prepared, each containing a different form of nitrogen. The list included nitrogen as peptone, asparagin, ammonium chloride, ammonium sulphate and

1. Cent. f. Bakt. Abt. II, Bd. 7, p. 561. 1901.
2. Cent. f. Bakt., Abt. II., Bd. 12, p. 357; Bd. 16, p. 341. 1906
3. Lohnis, Handb. d. Landw. Bakt. p. 712.
4. Cent. f. Bakt., Abt. II., Bd. 29 p. p. 649, 650. 1911.
5. Cent. f. Bakt., Abt. 11., Bd. 29, p. 643. 1911.

sodium nitrite. With the exception of the peptone, a solution of each was prepared containing the nitrogen equivalent of a ten per cent. solution of $NaNO_3$. This was done so that the various agars would be comparable to the sodium nitrate series in point of nitrogen content. The percentage equivalents for the salts mentioned, corresponding to a 10 per cent solution of $NaNO_3$ are as follows:

Asparagin	8.8231 per cent
NH_4Cl	6.2887 per cent
$(NH_4)_2SO_4$	6.5894 per cent
$NaNO_2$	8.1189 per cent

The proteid (peptone) agar was made by adding to the stock glucose agar, standard nutrient broth, neutral in reaction, in the following proportions: 0.0, .1, .2, .5, .8, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, and 10.0 per cent. The other agars were prepared by adding to respective lots of stock glucose agar the above solutions in amounts corresponding to 0.0, .01, .03, .05, .08, 0.1, 0.3 and 0.5 per cent of $NaNO_3$. For every 50 c. c. of the stock glucose agar the following quantities of these solutions were required to give the above percentages: 0.0 c. c., .05 c. c., .15 c. c., .25 c. c., .4 c. c., .5 c. c., 1.5 c. c. and 2.5 c. c. respectively. The six different agars were placed in test tubes using about 7 c. c. each, sterilized in the autoclave for five minutes at 120°C. and slanted. Stroke cultures were made on these employing cultures Nos. 3, 8, 93 and our stock culture of A. chroococcum.

At the end of eighteen days, there was no brown pigment produced by any of the cultures on the proteid nitrogen agar containing beef broth, although there was luxuriant growth in all of the tubes. No pigment whatever, was made by any of the cultures on either the amido nitrogen agar, containing asparagin, or the ammonia nitrogen agars, containing respectively NH_4Cl and $(NH_4)_2SO_4$. The growth ranged from slight to moderate. On the nitrite nitrogen agar, with cultures Nos. 8 and 93, we obtained a decided chocolate brown in the tubes which contained the $NaNO_2$ corresponding to .01 per cent $NaNO_3$. All of the inoculations with these two organisms grew, but without color. Culture No. 3 gave a brown and chocolate brown pigment with $NaNO_2$ corresponding to .01 and .03 per cent $NaNO_3$ respectively. The stock culture of A. chroococcum grew very feebly on this agar as on the others, and produced no pigment. Control cultures on the stock glucose agar, to which no nitrogen was added, were carried along with the above. Growth took place but there was no evidence of any pigmentation.

The results of this work indicate that in the presence of nitrates, A. chroococcum produces an intensely brown to black pigment; that nitrites in certain proportions, exercise this influence to a less degree; and that nitrogen as NH_4Cl, $(NH_4)_2SO_4$, asparagin, and peptone has no effect upon this function.

Solubility of the Pigment.

In their extended studies on the formation of pigment by A. chroococcum, Beijerinck[1], Omeliansky and Ssewerowa[2] have found that the pigment is insoluble in the ordinary solvents. On this point, Beijerinck says, "Insoluble in water, alcohol, ether, chloroform, carbon disulphide, the pigment went into solution under the influence of alkalies, whereby it probably underwent a chemical change." Omeliansky and Ssewerowa state that, "The pigment is insoluble in the usual solvents. Only under the action of alkalies does it go into solution, thereby, nevertheless, changing itself chemically."

The relation of alkalies to the solution of pigment, as described by these investigators, suggests a further explanation for the brown stain which we find on the ditch banks and irrigation furrows. May it not be possible that under the influence of the soil nitrates, Azotobacter chroococcum produces an intense pigment which is brought into solution by the alkaline soil waters, and once in solution, the coloring matter is carried to the surface where it becomes concentrated and produces the characteristic appearance? While we have given but little consideration to this explanation of the color, we have reasons for believing that there is more to this hypothesis than mere speculation and idle fancy.

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SUMMARY.

The power to fix atmospheric nitrogen is a property common to many cultivated Colorado soils.

This power is not confined to nitrogen fixation in solutions, but is manifested in soils as well.

"The rate of fixation of nitrogen obtained is sufficient to account for the nitrates found in the soil provided that it is nitrified. The rate of nitrification obtained is sufficient to account for the formation of the nitrates found, in most cases if not all of them."[3]

The nitrogen fixing power is not limited to any geographical locality or class of soils, however, the adobe shale soils, both in a raw

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[1]Loc. cit., page 39.
[2]Loc. cit., page 39.
[3]Bulletin 178, p. 96, Colo. Exp. Station, 1911.

state and newly cultivated, possess little, if any, nitrogen fixing power.

Excessive nitrates either destroy or greatly attenuate the nitrogen fixing flora of a soil.

A limited amount of soil nitrate does not seriously affect the nitrogen fixing power of a soil.

Azotobacter chroococcum appears to be the dominant nitrogen fixing organism in the soils studied.

The dark brown color of the nitre soils is due, in a large part, to the pigment produced by Azotobacter chroococcum.

Given a source of energy, the nitrate is the limiting factor in the production of the brown color.

In the presence of nitrates, Azotobacter chroococcum develops a chocolate brown to black pigment; nitrites, in certain amounts, produce similar results, but to a less degree; nitrogen as NH_4Cl, $(NH_4)_2SO_4$, asparagin, and peptone has no effect upon this function.

The highly colored extracts obtained from certain nitre soils suggest that the pigment of Azotobacter chroococcum may be soluble in the alkaline soil waters.

Excessive soil moisture, by interfering with the growth of Azotobacter chroococcum, prevents the formation of the brown color on the soil, and makes the fixation of atmospheric nitrogen impossible.

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